Very Preliminary

Wage Inequality in Taiwan and Its Causes

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Abstract

Using a household survey data from Taiwan's DGBAS, we found a trend of generally shrinking wage inequality from 1991 to 2015 between the top and the bottom labor earners, and between workers with high educational degree and those without. The wage inequality between different skill workers, however, generally remained flat. We, by using models adapted from the "skill-biased technological change" (SBTC) framework, proposed a formal test to untangle the potential demand side and supply side effects through trade, technological development, and human capital investment on the wage behavior in Taiwan.

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1 Introduction

Wage stagnation and the deterioration in income inequality by such measures as the Gini coefficient and the Oshima index have become social and economic worries in Taiwan. While how "good" these inequality measures can reflect the dynamics of Taiwan's income distribution is still under debate (Kuan and Chen, 2010), it seems to us that the dynamics of wage distribution in Taiwan still skipped serious academic attention.

The purpose of this paper is twofold. First, we try to create a fact sheet about the evolution of Taiwan's wage structures from 1991 to 2015 by integrating two rotating panel datasets, the Manpower Surveys and the Manpower Utilization Surveys, complied by the Taiwanese government. This fact sheet would provide various time-series wage profiles by education, occupation, or industry, and by distinguishing between different deciles of the wage distribution.

Second, given the history of wage dispersion from the fact sheet, we would like to ask, in addition to some plausible institutional factors and cyclical shocks, what secular forces from the supply and demand sides might affect the evolution of real wages in Taiwan.

The result of the first part of the research is somewhat against our prior (and perhaps baseless) expectation of an enlarging wage inequality. There is no apparent secular trend that wage inequality in Taiwan has deteriorated over the time period we studied. The overall wage gaps in terms of ratio of the best paid 10 percent to the worst-paid 10 percent (90/10) has actually shrunk (by 26% from 1991 to 2015). And the ratio of the upper 50 percent to the lower 50 percent (50/50) also decreased, albeit by a smaller scale. When looking at the between-education-group wage differentials, the college/high school premium has also been generally shrinking.

Dynamics of wage dispersion may look different from different perspectives, though. First, if we observe the upper and lower halves in wage distribution separately, we find divergence in the evolvement of wage gaps. Wage inequality in the upper half of the distribution (90/50) shows no sign of a secular decline. If we classify workers' educational attainments in a college/vocational/high school fashion, then while the college/vocational premium also displays a declining pattern, the vocational/high school wage gap has modestly enlarged. Second, when we observe the between-occupation wage differentials, we find both the high-skilled/middle-skilled wage gap and the middle-skilled/low-skilled wage inequality basically display neither increasing nor decreasing trend.

What can explain our finding when both the popular media and some academic literature blamed that globalization, the skill-biased technological progress, or substitution of computerized capital for labor have deteriorated income inequality? One possibility is that, as some authors have demonstrated, trade and technological development indeed have some adverse effects on the less-educated or low-skilled workers in developed countries (see for example Harrison, McLaren, and McMillan, 2011; and Acemoglu and Autor, 2011), the supply force from investment in human capital is also at work and offsets to some degree the adverse effects from the demand side.

Taiwan has aggressively embraced all the above-mentioned three activities: global division of labor, information and communication technologies, and human capital investment. The ratio of its commodity exports to GDP was between over 50% to near 65% in the last decade. It has had huge amount of foreign direct investment (FDI) in China. The number of jobs in Taiwan that contribute to the production of goods and services that are either consumed in other countries or further processed in other

countries, according to ILO (2015), is more than half of all workers employed, the largest among all the economies studied by ILO.

Taiwan is also an ardent follower (and a major producer) of the information and communication technology products. Taiwanese businesses' adoption of the internet technologies, according to the World Economic Forum's *Global Information Technology Report* (2011-2015), is usually among the top of the countries surveyed.

And, Taiwan has gone through a huge expansion in higher education in the last three decades. The percentage of Taiwan's 18-21 year old population who are enrolled in a college has grown from 21% in 1991 to (my goodness!) over 70% after 2013.

Interactions of these activities, which could greatly influence the demand for and supply of labor, might be complex. In the second part of the paper, by using models adapted from the "skill-biased technological change" (SBTC) framework, we work on a formal test, trying to untangle the potential demand side and supply side effects through trade, technological development, and human capital investment on wage dispersion in Taiwan.

The rest of the paper is ordered as follows. In Section 2 we describe the data source we used for empirical investigation, and then document the evolution of Taiwan's wage dispersion and the employment share from 1991 to 2015. In Section 3 we discuss possible explanations, from both the demand and supply sides, for the behavior of Taiwan's wages and employment shares, and propose the econometric models for testing the supply-and-demand hypotheses. Section 4 presents the regression results. Section 5 is a summary and an assessment of this work.

2 Behavior of Taiwan's Wage Dispersion and Employment Shares

2.1 Data Source

Our empirical analysis draws on two rotating panel datasets from Taiwan's Directorate General of Budget, Accounting and Statistics (DGBAS): the monthly Manpower

Survey (MS) and the yearly Manpower Utilization Survey (MUS). Both are household surveys since 1978, and the MUS is based on the MS and supposed to be a supplementary to it.

Each survey covers about 26,000 to 30,000 households at every turn. The respondents of each survey are civilian population aged 15 years and over, excluding military personnel and institutionalized population. Due to questionnaire redesign over the years and the resultant difficulties in connecting the old surveys with the recent ones, we confine our sample to the surveys after 1991. We further confine our interest of study to the private sector employees, thus excluding the employers, the self-employed workers, and the civil servants. As a result, there are about 18,000 to 20,000 observations left each year for analysis.

Major survey questions for the respondents in the MS include: sex, age, marital status, educational attainment, major(s) in school, employed status, hours of work in the most recent week, unemployed respondent's willingness to find a job, working location, number of employees of the company the respondent was working in, industry, occupation, type of employment status, etc. In the MS major survey questions include: monthly labor earnings, employment type (full-time or part-time), experience (working years) in the current working place, and various questions about the respondent's experience and willingness in job changes or job searching.

There are also two major establishment-based wage and salary surveys. One is the monthly Employees' Earnings Survey (EES), a payroll survey of the private and government employers in 17 major non-agricultural industries by DGBAS. The survey collected data on the numbers of employees, employee turnovers, working hours, and monthly salaries or wages. However, it lacks workers' demographic information we need for between-group analysis and regression.

Another payroll survey is the yearly Survey on Earning by Occupation (SEO) by the Ministry of Labor (MOL) started in 2003. The survey collected data, from private and public-own firms of non-agricultural industries, on the number of employees, monthly salaries or total wages, the firm's expected employee turnovers by occupation, and the monthly regular pay (which does not include the overtime pay) by educational attainment to employees who were new entrants of the labor market when entering the company within the last three years. The survey, in addition to being relatively new, also lacks workers' demographic information.

2.2 The Evolution of Taiwan's Wage and Employment Structure

2.2.1 Evolution of Wage Inequality

Taiwan's labor market appears to have encountered a structural transformation over the last several decades. Its unemployment rate has risen from an average of 2.17% in the 1990s to 4.63% in the 2000s and 4.11% from 2001 to 2015. Real hourly and monthly wages have been stagnating since the early 2000s.

Figure 1 displays the evolution of real hourly wages for male and female workers. While both the males and females had seen growth in their real wages in the 1990s, the wage for males evidently declined after the year 2000. (The compound annual growth rates of male workers' real hourly wages during 1991-1999, 1999-2009, and 2009-2015 are, respectively, 2.75%, -0.08% and -0.43%.) Females' real wage, though with no apparent secular decline, has also stagnated ever since. (The compound annual growth rates of female workers' real hourly wages during the same periods are respectively 4.15%, 0.37% and 0.55%.)

While the stagnation in real wages is evident, the evolvement of Taiwan's wage inequality has not, to our best knowledge, been thoroughly examined. Here we use the integrated MS and MUS data set to study the change in Taiwan's wage distribution over the last three decades.

We focus on both the overall and between-group measures of wage inequality, including: (1) changes in overall wage inequality, summarized by the ratio of the average real wage of the top 10 percent to that of the bottom 10 percent (the 90/10 wage

gap) and the 50/50 wage gap; (2) changes in inequality in the upper and lower halves of the wage distribution, summarized by the 90/50 and 50/10 wage gaps; (3) changes in between-education-group wage inequality, summarized by two kinds of measures, one being the college/non-college premium and another being the college/vocational and high school/vocational wage gaps; (4) changes in between-occupation wage inequality, summarized by the so-called abstract non-routine/routine and manual non-routine/routine wage gaps.

First the overall wage inequality. Figure 2a shows, except two temporary increases in the early and late 2000s, wage inequality between the best-paid ten percent and the worst-paid 10 percent shows no sign of secular augmentation, but has actually shrunk by 26% from 1991 to 2015. The ratio of the average earning of the upper-half earners to that of the lower-half (the 50/50 wage gap) behaved quite similarly, although it decreased by a smaller scale of 10% over 1991-2015 (Figure 2b).

When looking at the upper and lower halves of earnings separately, things seem to be a bit different. The wage gap between the top 10 percent and the median wage had no clearly downward or upward trends (Figure 3a,). The wage gap between the median wage and the bottom 10 percent, however, has shrank by 27% from 1991 to 2015 (Figure 3b).The force that narrowed the overall wage gap seems to be from the changes in the lower half.

Evolution of between-group wage differentials might offer hints at the (compositional or causal) sources of the decline in overall wage gaps. We therefore inspect the between-education-group wage differentials. We first study changes in wage ratio of workers with a college degree or more (which includes a vocational college degree) to those without a college degree (which includes a vocational high school degree). Then we study the changes in the wage ratio of workers with a four-year-college degree to those with a vocational degree, and those with neither college nor vocational degrees to those with a vocational degree.

Figure 4a displays the evolution of the real hourly wages of workers with a college degree or more and those without a college degree. Both workers have a somewhat similar pattern in wage changes to that of male and female workers (Figure 1), i.e., the wages having risen before the 2000s but turned declining thereafter, with a more pronounced decline for the workers with a college degree or more. The college/non-

college wage premium, somewhat similar to the changing path of the overall wage inequality, has also declined generally except for temporary increases between the late 1990s and the early 2000s (Figure 4b).

We can instead classify the educational attainments by college, vocational, or high school to examine the between-education-group wage gaps. As shown in Figure 5a, it's the real college wage that went through the most drastic decline after approximately the year 2000. The real vocational wage has remained roughly flat since 2000 and the high school wage decreased slightly. Thus the college/vocational and the high school/vocational wage gaps also shrank gradually with a similar pattern to the overall wage inequality (Figure 5b). The diminishing high school/vocational wage gap means that its reverse, the vocational/high school wage gap, was enlarging.

Next we consider the over-time variation in wage gaps between occupations. Since Autor, Levy, and Murnane (2003), some researches have tried to examine the sources of wage inequality through the lens of the "routineness" of job tasks. We, following Autor (2015) and World Bank (2016), divide occupations into three groups, indicating the different properties of tasks performed in those occupations (or the skills needed for workers in performing their tasks). The first is the occupations of the "abstract non-routine" tasks (or the "high-skilled" occupations), including legislators, senior officials and managers, professionals, and technicians and associate professionals; the second the occupations of the "routine" tasks (or the "middle-skilled" occupations), comprising clerical support workers, craft and related trades workers, plant and machine operators and assemblers; and the third the "manual non-routine" occupations (the "low-skilled" occupations), referring to service and sales workers and elementary labourers.[2]

Figure 6 displays the over-time changes in wage ratio of the abstract non-routine to the routine task occupations and those of the manual non-routine to the routine ones. The wage ratio of the abstract non-routine to the routine task occupations, unlike the wage ratio of the more schooling to the middle or less schooling workers, shows no sign of secular declining, but has been roughly flat with temporary increase in the early 2000s. The wage ratio of the manual non-routine to the routine task occupations has

[2] In this paper we include skilled agricultural, forestry and fishery workers into the manual non-routine occupations. As the number of this type of workers is small in Taiwan, It would make no big difference quantitatively in the pattern of descriptive statistics whether to include or exclude it from these three groups of occupations.

also been basically flat since the early 1990s.

We further examine if the between-occupation wage gaps behaved differently across industries. While the real wages in the manufacturing and the service industries share a similar evolution pattern to the changes in overall real wages, the real wages of the service industries are mostly higher in both level and growth than those of the manufacturing sector (Figure 7a). The advantage of services sector workers in both the level and the growth of wages receded after the early 2000s, however (Figure 7b).[3] The abstract non-routine/routine wage ratio of the manufacturing shows a pattern similar to that of the overall economy—roughly flat except a temporary increase around the early 2000s. The ratio in the service industries, however, demonstrates a sharper upward trend before the mid-2000s but a similarly sharp drop after it (Figure 9a). The manual non-routine/routine wage ratio, on the other hand, has had a roughly flat trend in the manufacturing, but an upward trend after the early 2000s in the services (Figure 9b).

The basic messages about the evolution of Taiwan's wage inequality can be summarized as follow. (1) The overall wage inequality measures (90/10 and 50/50) have been generally shrinking over 1991-2015. Except that the inequality measure of the upper half of the wage distribution (90/50) shows no sign of a secular decline. That's the lower half inequality measure (50/10) that has contributed to the overall decreasing inequality. (2) As for the between-education-group wage differentials, the college/high school premium has been, similar to the evolvement of the overall 90/10 and 50/50 measures, generally shrinking. With the three-dimensional classification of the schooling backgrounds, college/vocational premium has also displayed a secularly declining pattern. However, the vocational/high school wage gap has enlarged, though by a relatively small scale. (3) The between-occupation wage differentials show no sign of shrinking over time. The abstract non-routine/routine wage gap has been roughly flat except a temporary increase around the early 2000s in both the overall economy and the manufacturing industry, and had an also temporary but relatively sharp increase around the mid-2000s in the service industries. The manual non-routine/routine wage gap has also remained roughly flat in both the overall economy and the manufacturing

[3] In addition to a decline in real wages after the early 2000s, variation in real wages in both the manufacturing and services industries have also shrunk since the early 2000s, and the real wage of the service industries has consistently had a larger variation than that of the manufacturing sector (Figure 8a and 8b).

industry, and had an upward trend after the early 2000s in service industries (so the reversed routine/manual non-routine inequality measure has been decreasing after the early 2000s).

2.2.2 Employment Evolution

Given the evolvement of between-group wage inequality reviewed above (i.e., changes in the wage gaps between workers of different educational attainment, and those of different occupations), we next examine the corresponding evolvement in employment shares.

The employment share of male workers has gradually declined since the early 1990s. The share of female workers, on the other hand, has steadily grown (Figure 10). (The compound annual growth rates of employed male population during 1991-1999, 1999-2009, and 2009-2015 are, respectively, 1.13%, -0.77% and 0.72%; and those of employed female population are respectively 1.12%, 0.54% and 0.54% .)

As shown in Figure 12a and 12b, the relative employment share of workers with a college degree or more (including a vocational college degree) to those without a college degree (including a vocational high school degree) has soared, reflecting the huge expansion of Taiwan's higher education in the last three decades. (The percentage of Taiwan's 18-21 year old population who are enrolled in a college has grown from a mere 21% in 1991 to over 70% after 2013). A mechanical force due to the gradual retirement of elder workers, who are in general less schooled, might also be at work. Alternatively, if we inspect the workers' schooling backgrounds from the college/vocational/high school dimensions, we also find that the share of workers with a four-year-college degree or more has soared, accompanied by a plunge in the share of workers with neither college nor vocational degrees. The share of workers with a vocational degree, however, ascended before the 2000s but descended afterwards (Figure 13a). Hence the employment ratio of the college to the vocational workers inflated and the ratio of the high school to the vocational workers shrank (Figure 13b).

Next we inspect the changes of employment share by occupation. Figure 14a reveals that both the shares of the abstract non-routine and the manual non-routine task occupations have risen steadily since the early 1990s, and the share of the routine task

occupations has been declining.[4] As a result, both the abstract non-routine/routine ratio and the manual non-routine/routine ratio have inflated (Figure 14b).

Given that Taiwan has seen a dramatic expansion in higher education over the last three decades, we further examine the employment shares of different occupation groups by educational level. Against the background that the college/high school employment ratio has inflated (see Figure 12), Figure 15a and 15b further demonstrate that, relative to being employed in the routine task occupations, a decreasing share of the college workers was employed in the abstract non-routine occupations, and an increasing share of them employed in the manual non-routine occupations. The high school workers, meanwhile, have seen a similar evolving pattern with the difference that a higher share of them was employed in the manual non-routine occupations than was employed in the abstract non-routine occupations (Fig 16a and 16b).

We further inspect the employment shares of different occupation groups by educational level from the college/vocational/high school classification. Again, relative to being employed in the routine task occupations, a drastically decreasing share of the four-year-college workers was employed in the abstract non-routine occupations, and an increasing share of them employed in the manual non-routine occupations (Figure 17a and 17b). The vocational workers also have had a decreasing share employed in the abstract non-routine task occupations as compared to in the routine ones, and an increasing manual non-routine/routine ratio (Fig 18a and 18b). The high school workers have seen, relative to being employed in the routine task occupations, an increasing share of being employed in the manual non-routine occupations and a roughly constant share in the abstract non-routine occupations (Fig 19a and Figure 19b).

We also examine if there is systematic difference in the changes in occupational shares across different industries. The evolution of employment shares between different industries. Figure 11a and 11b show that the employment share of the manufacturing, while consistently lower than that of the service industries, has declined steadily, and the employment share of the service industries has risen. Figure 20a through Figure 21b then demonstrate that the ratio of the abstract non-routine to the

[4] The figures for occupational employment share in 1991 and 1992 appear quite anomalous. Further examination and adjustments in connecting the recent MS and MUS surveys with the older ones will be needed.

routine occupations has been enlarging in both the manufacturing and service industries. The ratio of the manual non-routine to the routine occupations, however, has been increasing in the manufacturing but declining in the service industries.

Some basic messages can be drawn from our examination of the changes in between-group employment shares. (1) The employment ratio of college-education workers has soared. This could reflect Taiwan's recent expansion of higher education and a mechanical force due to the retirement of less-schooled elder workers. (2) Relative to the routine task occupations, both the abstract non-routine and the manual non-routine shares have gone up in both the overall economy and the service industries. In the manufacturing sector the abstract non-routine/routine ratio has also increased, although its manual non-routine/routine ratio has declined a little bit. At first appearance this looked like the "employment polarization" described by some literature on the structural change of labor markets in many developed countries (see, for example, Acemoglu and Autor, 2011; Autor and Dorn, 2013; Autor, Dorn, and Hanson, 2015; Dustmann, Ludsteck, and Schönberg, 2009; Goos and Manning, 2007; Goos, Manning, and Salomons, 2014; Tuzemen and Willis, 2013; World Bank, 2016). (3) However, if looking at the occupational shares by schooling backgrounds, there seems to be less apparent "polarization". Although the non-routine/routine ratio generally went up for workers of all schooling types (college, vocational, and high school), the abstract non-routine/routine ratio usually declined for both the college and the vocational workers, and remained roughly flat for the high school workers. This means that while there was an increasing share of college workers in the abstract non-routine task occupations, the share of college workers employed in the routine task occupations increased even faster, and their share employed in the manual non-routine task occupations increased the fastest.

3 Hypotheses and Empirical Models

What forces can explain the evolutionary pattern of Taiwan's wage inequality (and perhaps simultaneously the employment shares as well)? Potentially, many market and non-market forces could have influenced the overall and between-group wage inequality. Nonmarket factors might include such institutional forces as the changing real value of minimum wage or the enhanced or reduced role of labor unions (Card and DiNardo, 2002, 2006). The market factor, on the other hand, explains the change in

wage and employment through the lens of the supply of and the demand for labor skills.[5]

3.1 The Supply-and-Demand Perspective

Let's, for exemplary purpose, have the nonmarket and institutional factors fixed over time, and try to see intuitively whether Taiwan's changing pattern in wage inequality and employment shares reviewed in the last section can be (qualitatively and at least partially) explained by the supply-and-demand framework?

A typical proxy for the potential labor supply in literature is the relative employment share of workers of different educational attainment (Katz and Murphy, 1992; Acemoglu and Autor, 2011, 2012; Autor, Katz and Kearney, 2008; Dustmann, Ludsteck, and Schönberg, 2009), that is, the college/high school and college/vocational ratios studied in the last section. The dramatic expansion of the higher education over the last three decades in Taiwan, then, seems to be able to help us make sense of the shrinking overall inequality (W90/W10, W50/W50) and the shrinking college/high school and college/vocational wage premiums if we assume that the outward-shifted supply of more-educated works were not fully offset by any forces of labor demand. Through the lens of the increase in the relative supply of more-educated works, even a shrinking W50/W10 looked plausible (i.e., relatively too many high-educated workers having entered the low-paying sectors).

An exclusively supply-side view, however, has more difficulty in reconciling the evolvement of the between-occupation wage premiums with that of the between-occupation employment ratios. In both the overall economy and the manufacturing industry, as shown above for example, while both the abstract non-routine/routine and

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[5] Some authors also pay attention to the mechanical or compositional effects on the changes in overall or "within-group" (i.e., residual) wage dispersion. Holding market prices fixed, changes in such labor force composition as the distribution of workers' educational backgrounds or age (or experience) can mechanically raise or lower overall or within-group wage dispersion simply by altering the employment share of worker groups that have more or less dispersed wages (see for example Juhn, Murphy, and Pierce, 1993; Lemieux, 2006; Autor, Katz, and Kearney, 2008; Dustmann, Ludsteck, and Schönberg, 2009). Holding prices fixed when quantities is changing is, however, inconsistent with the general equilibrium framework. We forgo this analysis in this paper.

the manual non-routine/routine employment ratios have augmented, the abstract non-routine/routine and the manual non-routine/routine wage gaps have mostly remained flat. Given the fact that over time a predominant and increasing share of the increasing supply of better-educated workers entering into the abstract non-routine occupations, the augmented overall abstract non-routine/routine employment ratios accompanied with a mostly flat abstract non-routine/routine wage ratio would sound sensible in the lens of a supply-and-demand framework only if we assume that the demand for skills for abstract non-routine tasks has also shifted upward.

A similar supply-and-demand explanation might apply to the non-trending W90/W50, i.e., effects on wage from an increasing supply of more better-educated labor might be somewhat offset by an increasing demand for better-educated labor.

The intuitive explanation in terms of supply-and-demand for the case of an increasing vocational/high school wage premium accompanied with an increasing vocational/high school employment ratio might be more subtle. In this case, besides any possible reasons from the demand side, Taiwanese high school workers, whose employment share has been decreasing over time, have had to compete with an increasing supply of foreign immigrant workers, who were mostly manual labourers and whose number reached near 600 thousands, roughly equivalent to 5% of Taiwan's labor force, in 2015.

3.2 Candidate Forces Affecting Changes in Labor Demand

Taking the ratio of workers between different educational attainments as a proxy for relative labor supply, we would further ask what forces might affect the changes in labor demand in Taiwan? We discuss two of the prominent hypotheses on forces shifting labor demand in the developed countries: computer technologies and globalization.

3.2.1 Digital Technologies

The development of computer and digital technologies have been regarded, from the viewpoint of their potential ability in shifting labor demand, as an important candidate for explaining the behavior of wage dispersion and employment shares in developed countries. The "skill-biased technological change" (SBTC) theory, for example, explains the widening of wage inequality as a result of the race between technology and education where technological development increases the skill requirements in

production and hence raises the demand for skilled workers relative to that of unskilled workers. When demand moves outward faster than does the supply of human capital, inequality rises, and vice versa when supply outpaces demand (Katz and Murphy, 1992; Goldin and Katz, 2010).

The SBTC theory, however, seems unable to explain some important features in wage and employment evolvement in the USA and perhaps in some other developed countries (Card and DiNardo, 2002). It overstates the rise in the college premium in USA after the 1990s, and fails to explain how technological progress could produce widespread wage stagnation and an increase in the share of low-skill occupations. It also ignores the potential divergence in the pattern of wage inequality between the top and bottom halves of the wage distribution.

Given the potential drawbacks of the SBTC theory, a more nuanced technology-based explanation, the "tasks framework", was proposed (Autor, Levy, and Murnane 2003; Autor and Dorn, 2013; Acemoglu and Autor, 2011, 2012). It defines three kinds of tasks: non-routine abstract tasks (high-skilled), non-routine manual tasks (low-skilled), and routine tasks (middle-skilled). Computerization and Computers have the capacity to compete directly with workers who perform routine tasks (Frey and Osborne, 2017), but they are poor substitutes for workers performing non-routine abstract or non-routine manual tasks. The "tasks framework" could produce predictions of "polarization in employment", i.e., an increase in the employment share of both the high-skilled and low-skilled occupations, with a "hollowing out" in the middle. Further with some qualification on parameters, it could even predict "wage polarization": A rise in the wages of both the high-skilled and low-skilled occupations relative to those of the middle. How accurately these predictions can match the empirical behavior of wages and employment shares in USA and other developed countries, however, is still in debate (Mishel, Shierholz, and Schmitt, 2013a,b; Burtless, 2014; Krugman, 2015).

Could the SBTC theory or the "tasks framework", both of which focus on technology's impact on the demand for labor in the developed countries, explain the behavior of wages and employment shares in Taiwan we studied in Section 2 (which is the result of interactions between labor demand and supply)? At first glance, the generally shrinking or unchanged wage inequality in Taiwan over 1991-2015 is rather inconsistent with the predictions of an increasing college premium (SBTC) or the

"polarization" in employment or wages. Nevertheless, we need a formal test to untangle the potential influence from the demand side and that from the supply side.

We lack any detailed time series or panel data on the use of computers or internet by workers in Taiwanese businesses. However, according to some general surveys such as the World Economic Forum's *Global Information Technology Report* (2011-2015), Taiwan's networked readiness, including its computer-and-internet related infrastructure and its businesses' adoption of the internet technologies, is usually among the top 20 among the countries surveyed. It is interesting to see to what degree the computer and digital technologies might have influence on businesses' labor demand in Taiwan.

3.2.2 Trade and Offshoring

International trade is known for long for its possibly causing deterioration in domestic income inequality. The Stolper-Samuelson theorem implies that wages of skilled workers in developed countries, which has abundant skilled labor, should increase relative to unskilled workers and inequality should rise with trade. The opposite was expected to happen in developing countries. As a result, the growth of international trade may cause not just rising inequality but an actual decline in the wages of less-educated workers.

Some empirical evidence, however, including rising inequality in developing countries after trade and a rise in the level of skills within industries across the entire developed economy, is known to be at odds with the Stolper-Samuelson theorem and the Heckscher-Ohlin model in general. Feenstra and Hanson (1995) propose a theory of trade in tasks through offshoring, by which a firm producing in the skill-rich country allocates some least skill-intensive tasks performed at home to workers in the skill-poor country (modelled as an outward foreign direct investment from skill-rich to skill poor country). Since the tasks thus reallocated are more skill-intensive than the tasks initially done in the skill-poor country, the labor demand in both countries thus becomes more

skill-intensive at the same time. The equilibrium skill premium then rises in both countries. (See also Feenstra and Hanson, 1999; Feenstra, 2016; and Harrison, McLaren, and McMillan, 2011.)

Grossman and Rossi-Hansberg (2008, 2012) further propose, under some special assumptions, the theoretical possibility that offshoring can be Pareto-improving for the skill-rich country. Specifically, after offering the low-skilled task to a skill-poor country, the domestic low-skilled workers now can concentrate on the higher productive task that is left for home production, thus raising their productivity and wages without lowering wages for high-skilled workers in home.

What implications does a trade explanation for changes in labor demand have for Taiwan's labor market? Taiwan has always been a trade-oriented country since the 1960s. The ratio of its commodity exports to GDP was between over 50% to near 65% in the last decade, and the ratio of its commodity imports was between over 40% to near 60% in the same period. Taiwan's destination of exports concentrates on a few big markets, particularly China. Its exports to China have risen from a share of less than 1% in Taiwan's total exports in 1991 to 26% in 2015. Its imports from China have also greatly expanded, from less than 1% of the total imports to 19% during the same period. Moreover, due to the fact that over 75% of Taiwan's exports to Hong Kong was estimated to be actually re-exported to China, if we add Taiwan's exports to Hong Kong in those to China, then Taiwan's exports to China would have risen from 16% of Taiwan's total exports in 1991 to 39% in 2015. By the same token, the share of imports from China would have risen from 4% in 1991 to 20% in 2015.

Parallel to its close trade relationship with China, Taiwan's foreign direct investment (FDI) in China has also been enormous. The ratio of Taiwan's FDI in China to Taiwan's private fixed capital formation has risen from around 1% in 1991 to over 10% in 2015. And its accumulated direct investment in China from 1991 to 2015 totaled more than 60% of its all foreign direct investment accumulated, far outnumbering its foreign direct investment in any other country during the same period.[6]

[6] The statistical data of Taiwan's trade with China and its FDI in China are somewhat complex and have

Given Taiwan's deep involvement in the global supply chains (GSCs), we expect that the employment and income patterns of Taiwan would be in no small way affected by foreign trade or its offshoring activities, particularly through these activities' influence on the demand for labor in Taiwan. According to ILO (2015), Taiwan has more than half of all workers employed in GSC-related jobs, the largest among the 40 economies studied by ILO (followed by the Republic of Korea and the EU-27).[7]

To untangle the possible influence from labor demand through the channel of trade and offshoring on Taiwan's wage behavior, and the influence from labor supply, we again need a formal test.

3.3 Testing the Supply-and-Demand Framework

We use a simple supply-and-demand model to test what effects from labor supply and labor demand would have on wage dispersion in Taiwan. The benchmark model is as follows:

$$\log\left(\frac{W_{ct}}{W_{Nt}}\right) = \alpha_0 + \alpha_1 D_t + \alpha_2 \log\left(\frac{L_{ct}}{L_{Nt}}\right) + \alpha_3 (Institutional\ factors)_t + \alpha_4 (Cyclical\ factors)_t + \varepsilon_t.$$

In the above equation W_{ct} and W_{Nt} are, respectively, the real mean wage of employed workers with and without a college degree at time t, and hence the ratio W_{ct}/W_{Nt} stands for the wage gap between these two type of workers. L_{ct} and L_{Nt} are respectively the number of workers of these two types at time t, and hence the ratio L_{ct}/L_{Nt} is a proxy for the relative labor supply by education. D_t indexes shifts in relative labor demand. One possible institutional factor may be the real value of minimum wage, and the unemployment rate or the real GDP growth rate may be indicators for cyclical shocks.

multiple sources, which are not listed in the paper but are available upon request from the authors.

[7] For any given country, the number of its GSC-related jobs is defined by ILO (2015) as the number of jobs that contribute to the production of goods and services that are either consumed in other countries (i.e. final goods and services) or further processed in other countries (i.e. intermediate goods and services).

The model is actually a direct transplant from the conventional SBTC theory. We can explain the equation as the reduced form of a labor market equilibrium in which the firm has a standard CES production function with two factors (college and non-college equivalents), and that workers are paid their marginal products (Katz and Murphy, 1992; Acemoglu and Autor, 2011, 2012; Autor, Katz, and Kearney, 2008). The relative demand shifts D_t is not directly observed and subject to different interpretations about what empirical variables correspond to it. In regression the D_t could be technological development indexed by a linear or quadratic time trend, or such foreign trade forces as outward FDI, imports, or exports. Besides the contemporary measures for the independent variables, lag measures might also be used in regression.

The relative demand shifts D_t is, in the original SBTC context, expected to favor college equivalents. We could actually have the same expectation for its influence on Taiwan's better-educated workers in this regression from theories other than SBTC like the traditional Stolper–Samuelson theorem or the trade-in-task theory proposed by Freenstra and Hanson. However, under the context of Grossman and Rosssi-Hansberg's trade-in-task approach, D_t is expected to comparatively favor the less-educated workers.

Using the benchmark equation, we could also, in a somewhat *ad hoc* fashion, explore how the relative supply by education would affect the overall wage gaps (instead of the between-education-group wage differentials). So the wage gap W_{ct}/W_{Nt} in the equation may be replaced by the wage ratio of the best-paid 10 percent to the worst-paid 10 percent ($W_{90,t}/W_{10,t}$) or the wage ratio of the upper 50 percent to the lower 50 percent ($W_{50,t}/W_{50,t}$).

Alternatively, we might want to see whether the demand and supply forces might affect the upper and lower halves of the wage distribution in a different fashion. So we

propose two more regressions:

$$\log\left(\frac{W_{Ut}}{W_{At}}\right) = \beta_0 + \beta_1 D_t + \beta_2 \log\left(\frac{L_{Ut}}{L_{At}}\right) + \beta_3 (Institutional\ factors)_t + \beta_4 (Cyclical\ factors)_t + \epsilon_t$$

and

$$\log\left(\frac{W_{St}}{W_{At}}\right) = \gamma_0 + \gamma_1 D_t + \gamma_2 \log\left(\frac{L_{St}}{L_{At}}\right) + \gamma_3 (Institutional\ factors)_t + \gamma_4 (Cyclical\ factors)_t + \xi_t,$$

where W_{Ut}, W_{At} and W_{St} are, respectively, the real mean wage of employed workers at time t with a college degree, a vocational degree, and a high school degree or less. L_{Ut}, L_{At} and L_{St} are respectively the number of workers of these three types at time t.

In this case, we are assuming that there are two kinds of goods produced, and each good uses a common production factor L_{At} with one (L_{Ut} or L_{St}) different from the other's.

Using these two equations, we could also explore how the relative supplies of the three educational groups would, in addition to the relative demand, differently affect the measures of the upper and lower halves in the overall wage distribution. So the wage gap W_{Ut}/W_{At} might be replaced by $W_{90,t}/W_{50,t}$, and W_{St}/W_{At} be replaced by $W_{50,t}/W_{10,t}$.

Similarly, we can also test how the wage differentials of the abstract non-routine/routine occupations (W_{Ht}/W_{Mt}) would be influenced by the relative supply L_{Ut}/L_{At}, and the how the wage differentials of the manual non-routine/routine occupations (W_{Lt}/W_{Mt}) be influenced by the relative supply L_{St}/L_{At}. This regression could also form an indirect test for the "task framework" proposed by Autor and coauthors. The relative demand shifts D_t is, in this cast unlike the pure SBTC model,

expected to favor not only the high-skilled workers of abstract non-routine task, but perhaps also low-skilled workers of manual non-routine task.

Given our various interpretations of the expected impact of the unobserved D_t on relative wages, it sounds like anything goes, and these regression actually test nothing at all. However, we hope to see if the regression results would show some systematic pattern that favors some specific predictions from the trade or technology hypotheses.

4 Regression Results

[To be appended.]

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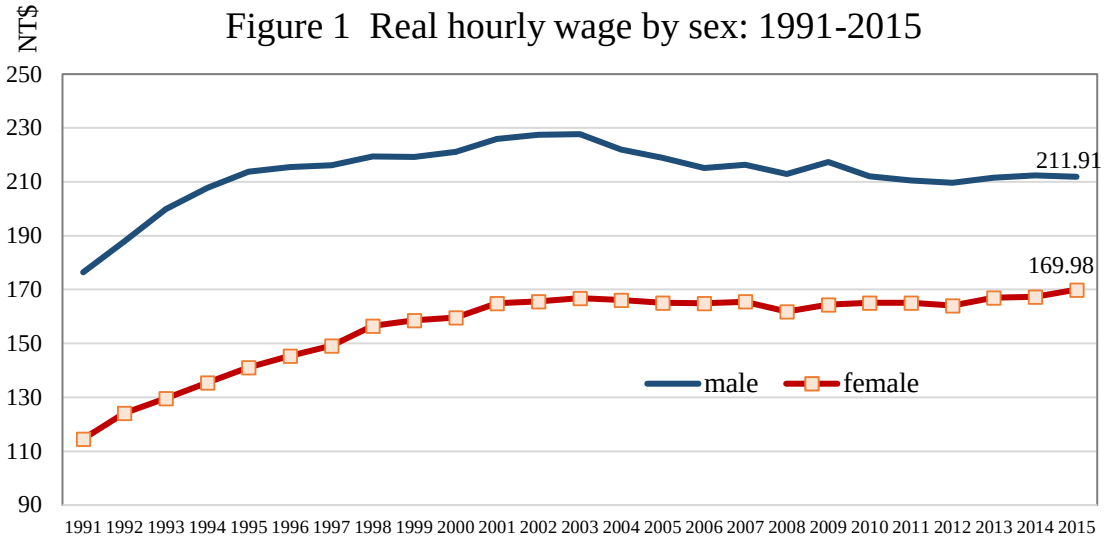
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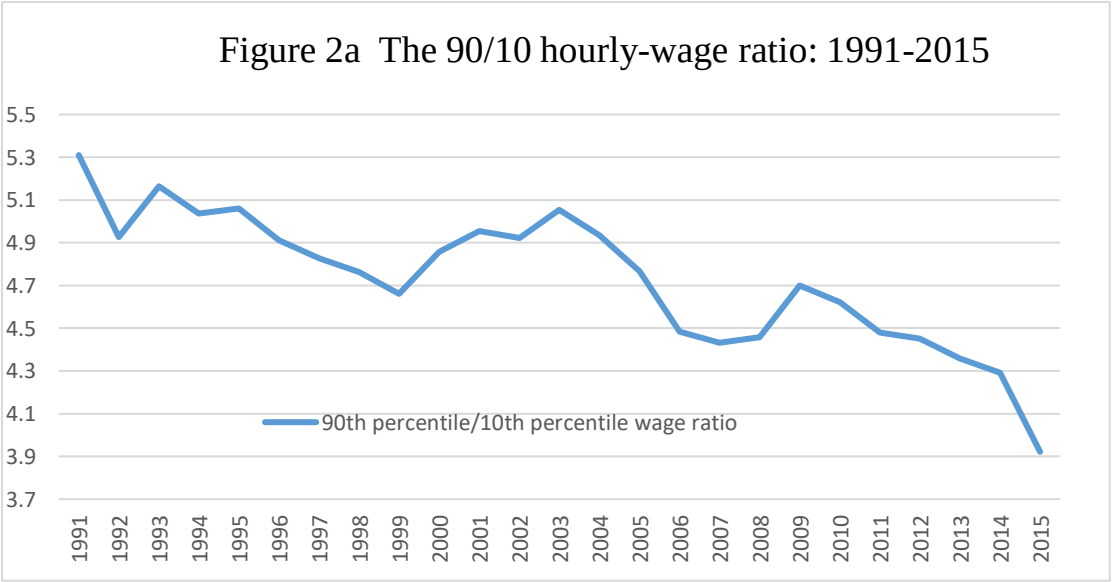
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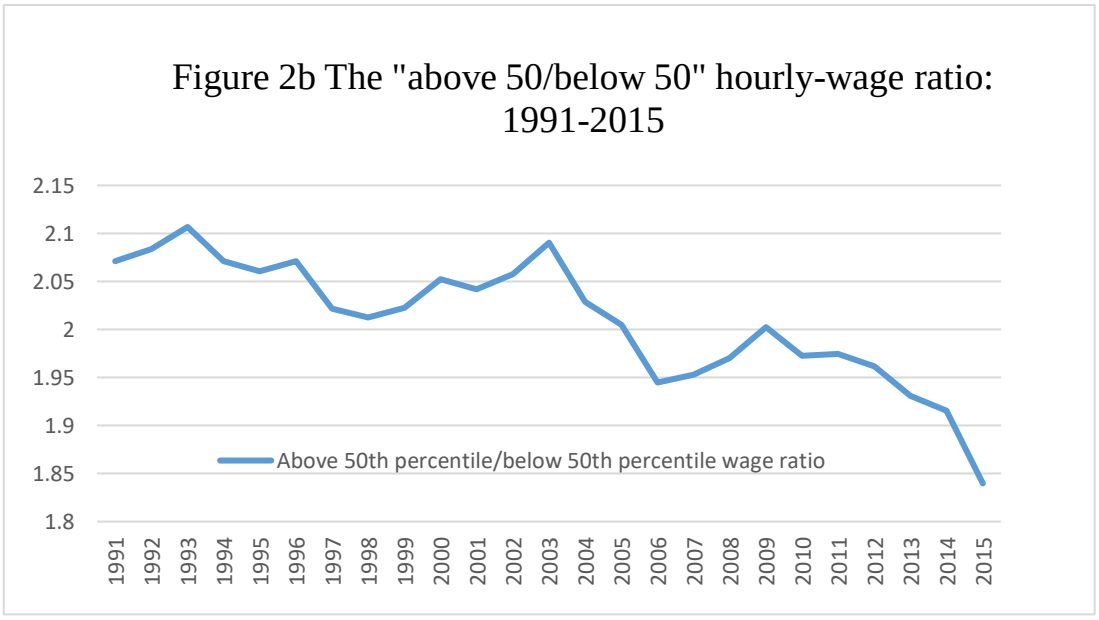
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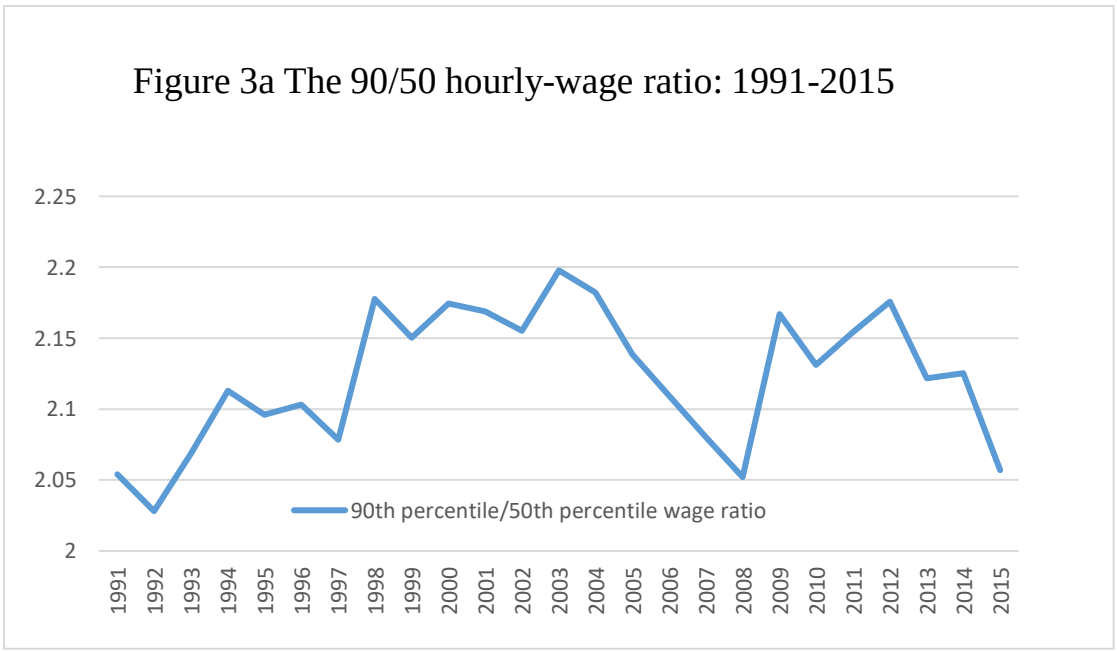
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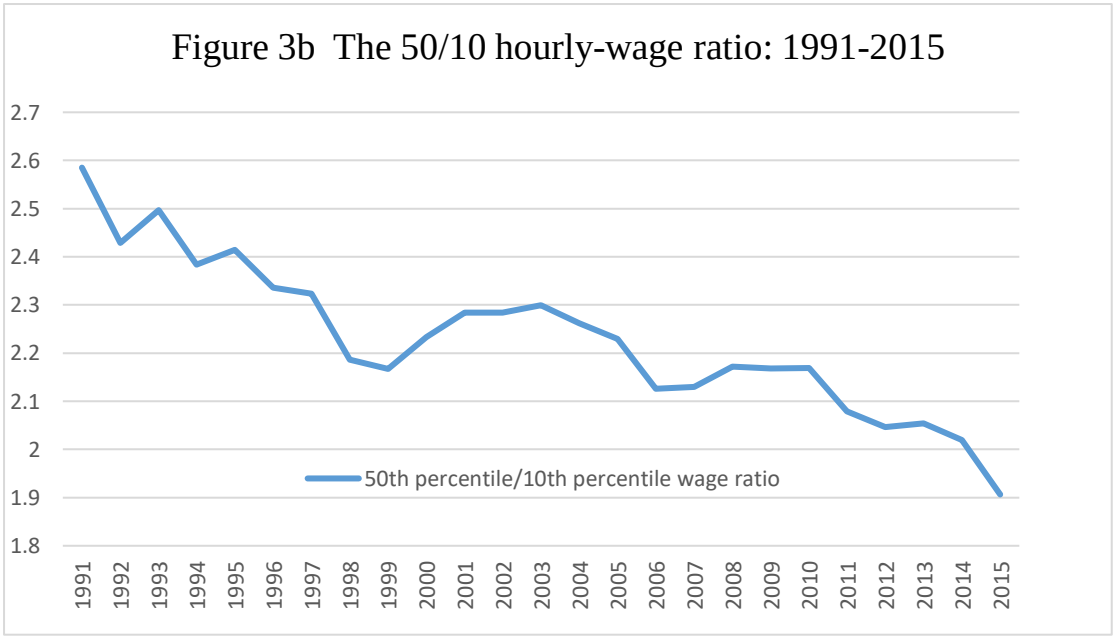
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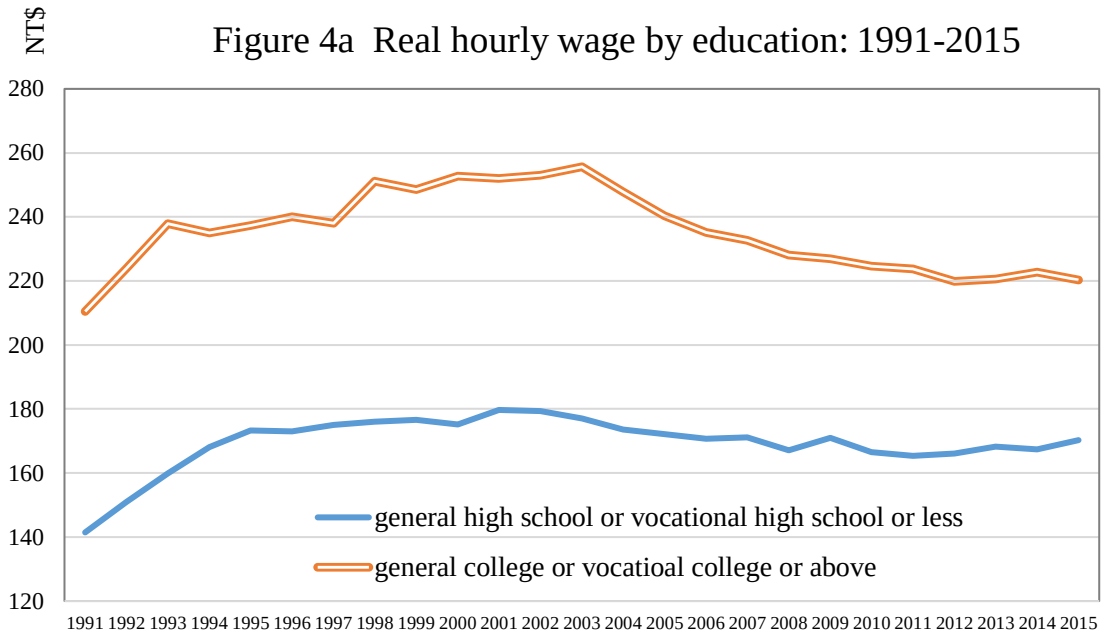
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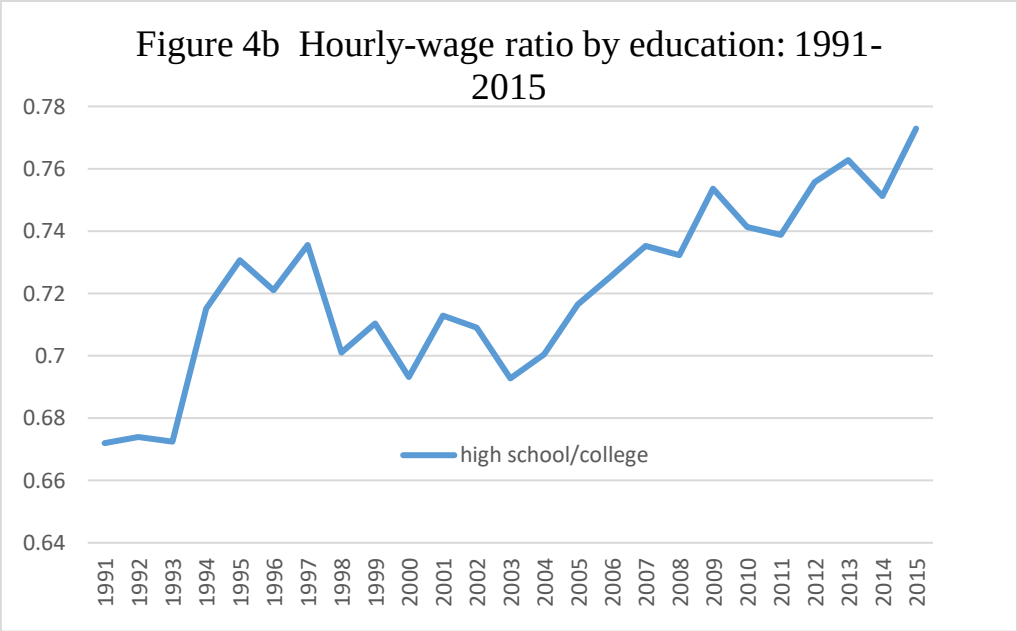
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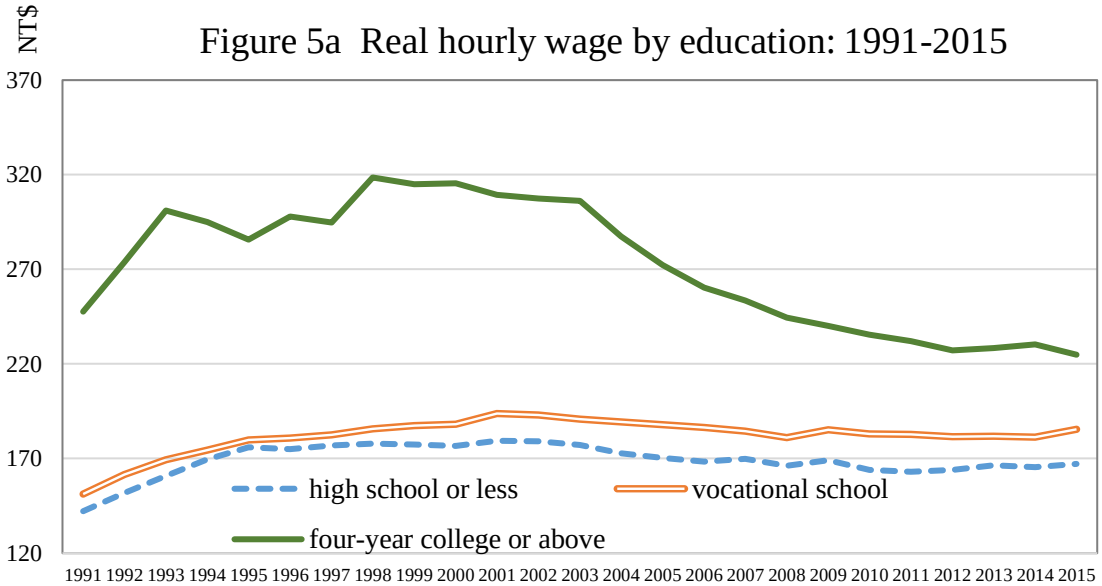
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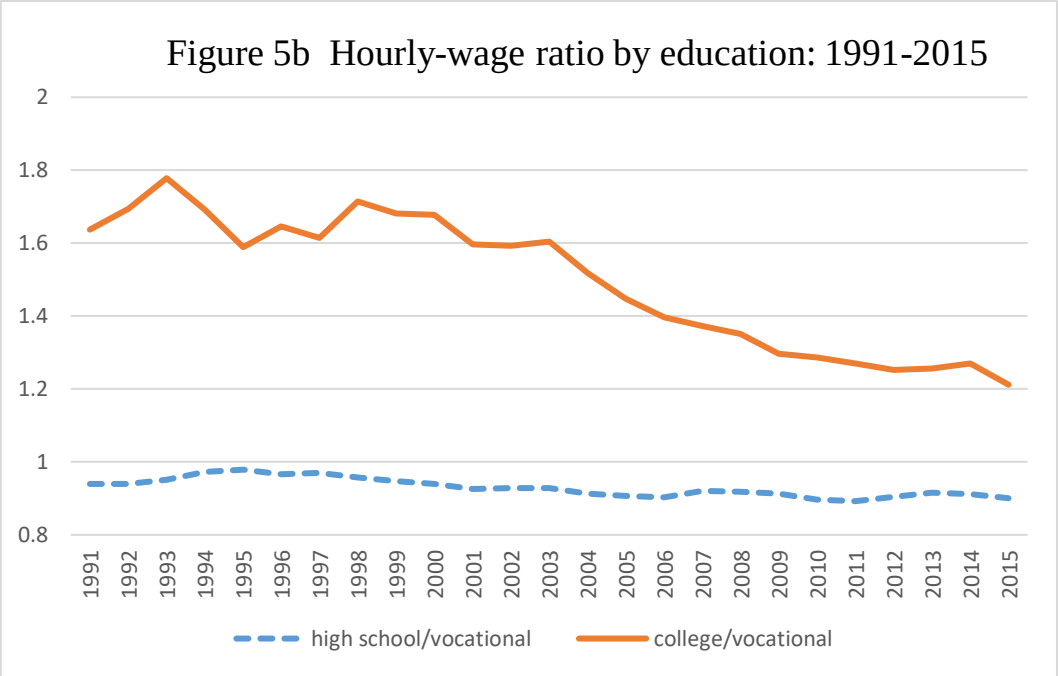
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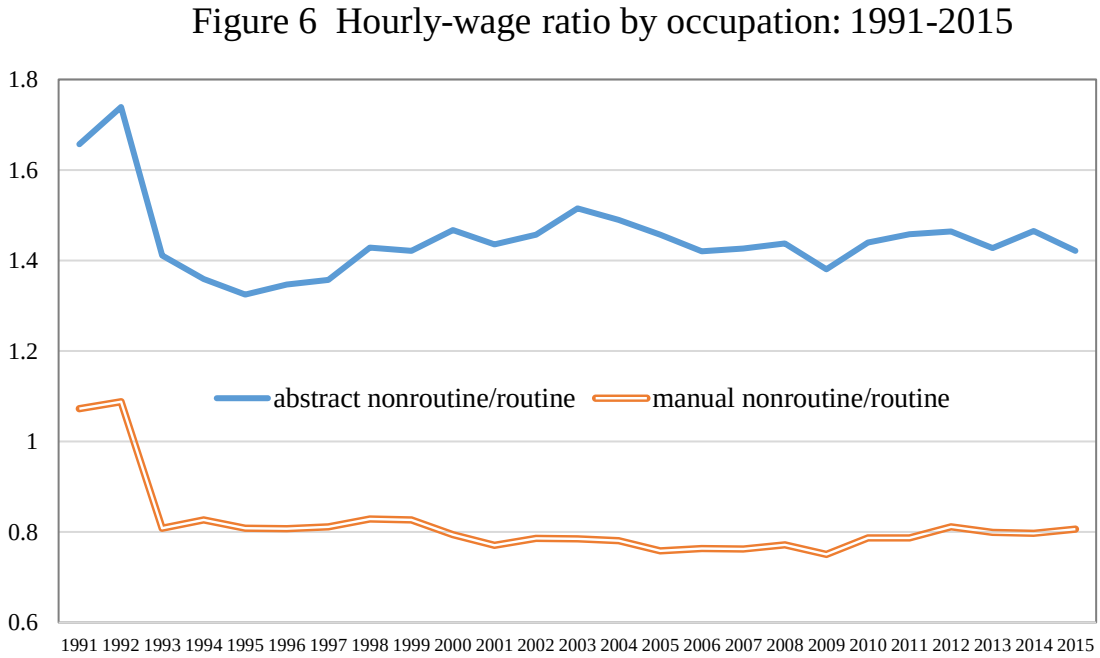
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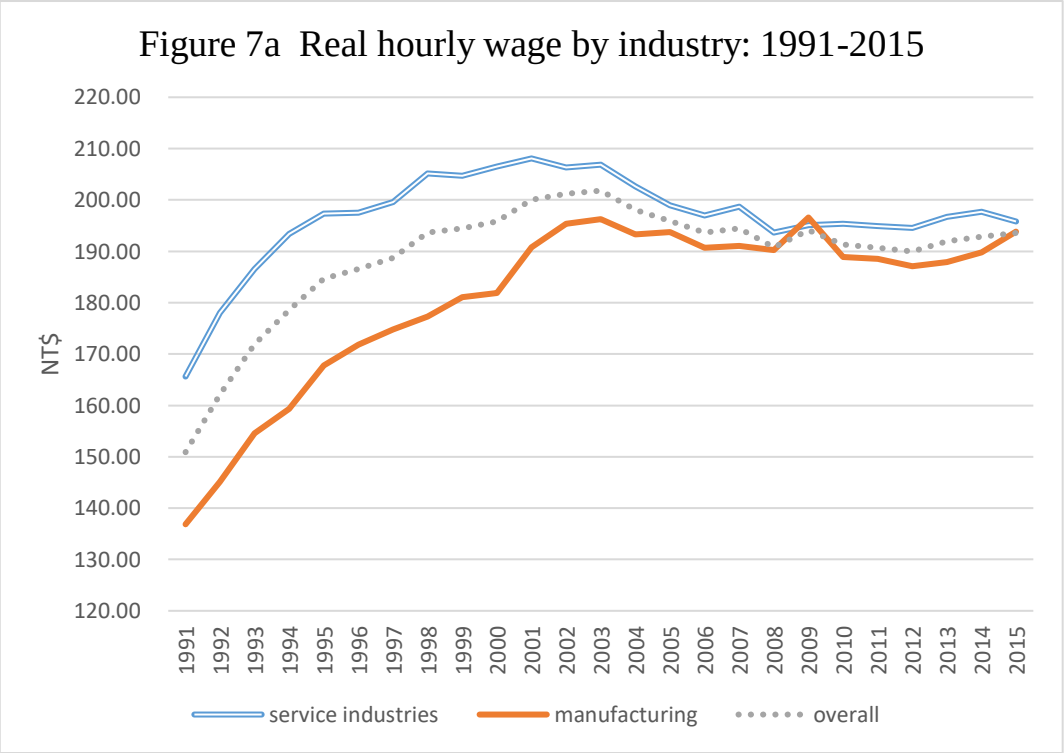
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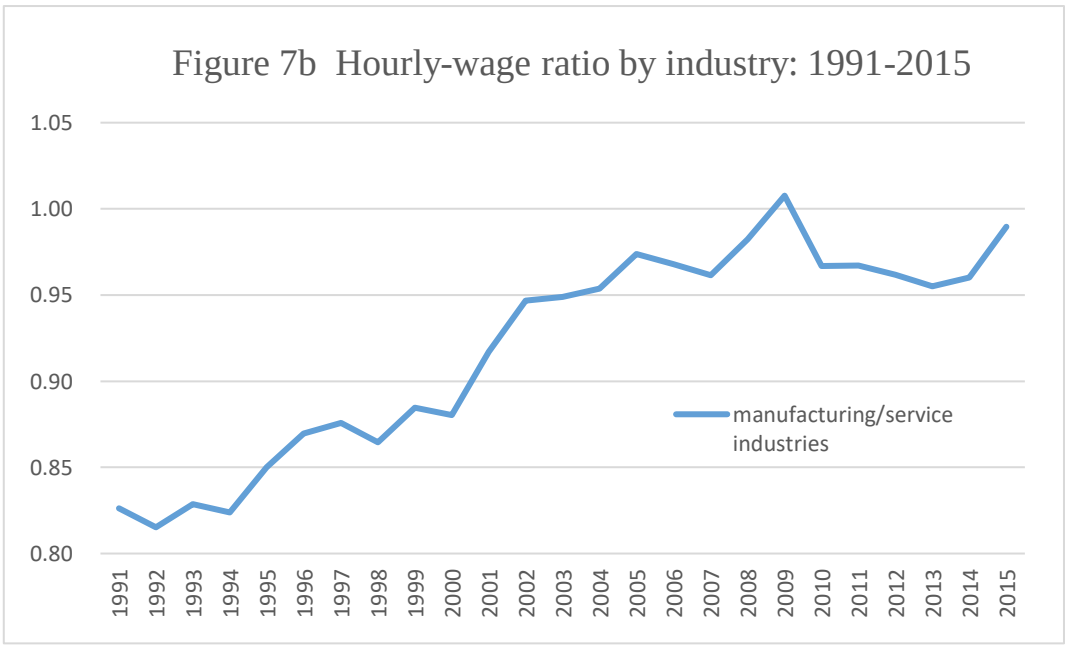
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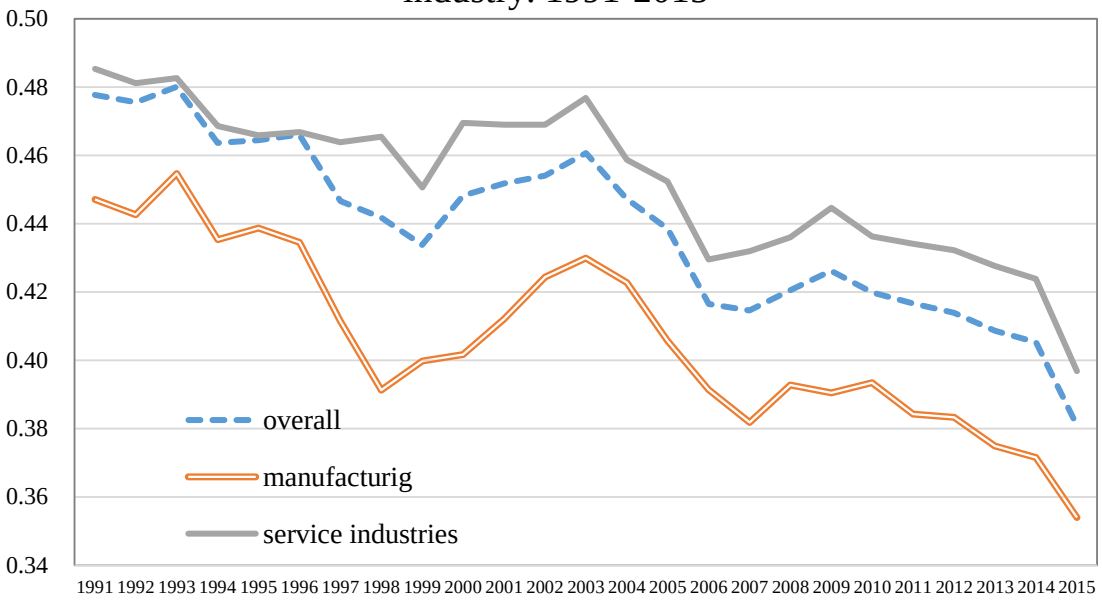


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Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 8a Standard deviation of log real hourly wage by industry: 1991-2015



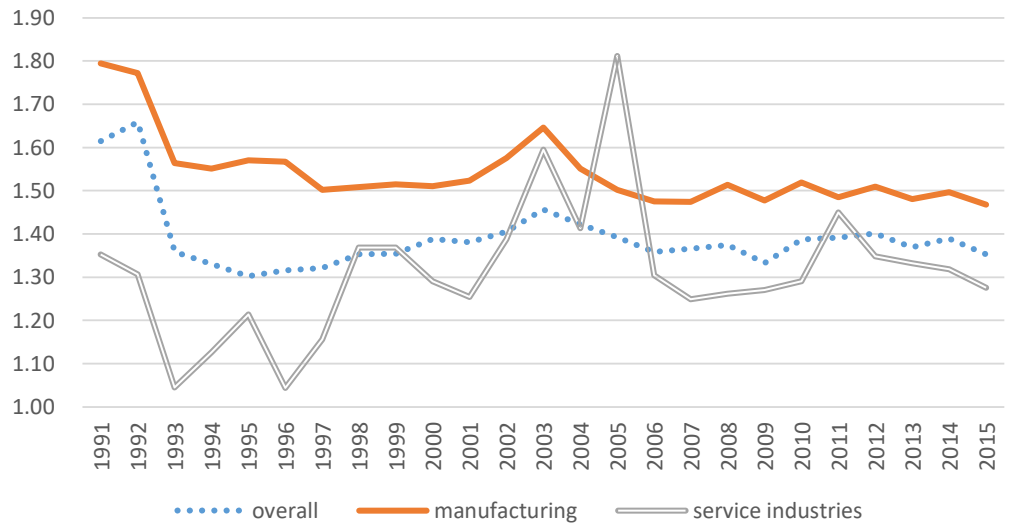
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Figure 8b Relative standard deviation of log real hourly wage by industry: 1991-2015



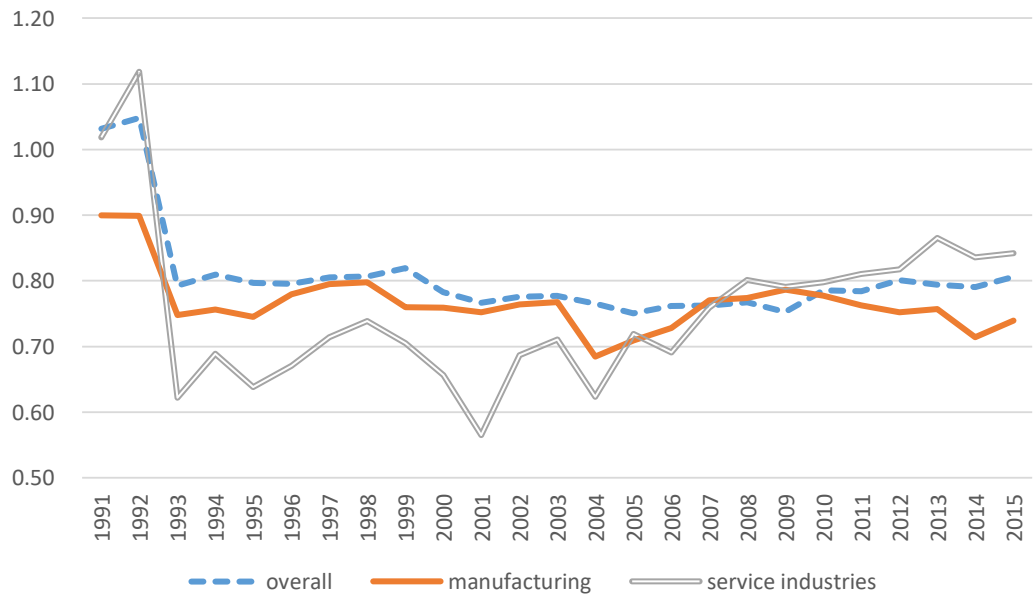
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 9a Hourly-wage ratio of abstract nonroutine occupations to routine occupations by industry: 1991-2015



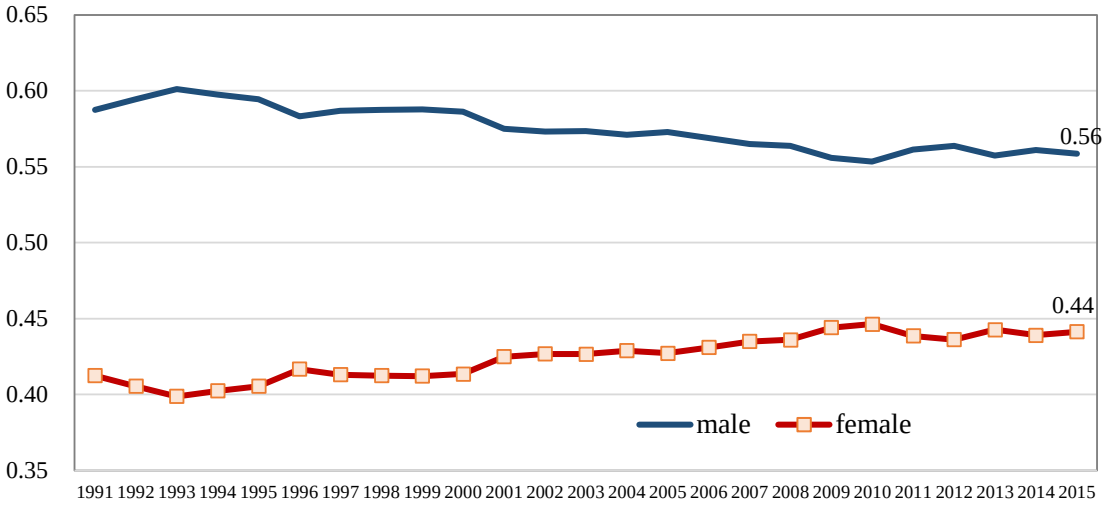
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 9b Hourly-wage ratio of manual nonroutine occupations to routine occupations by industry: 1991-2015



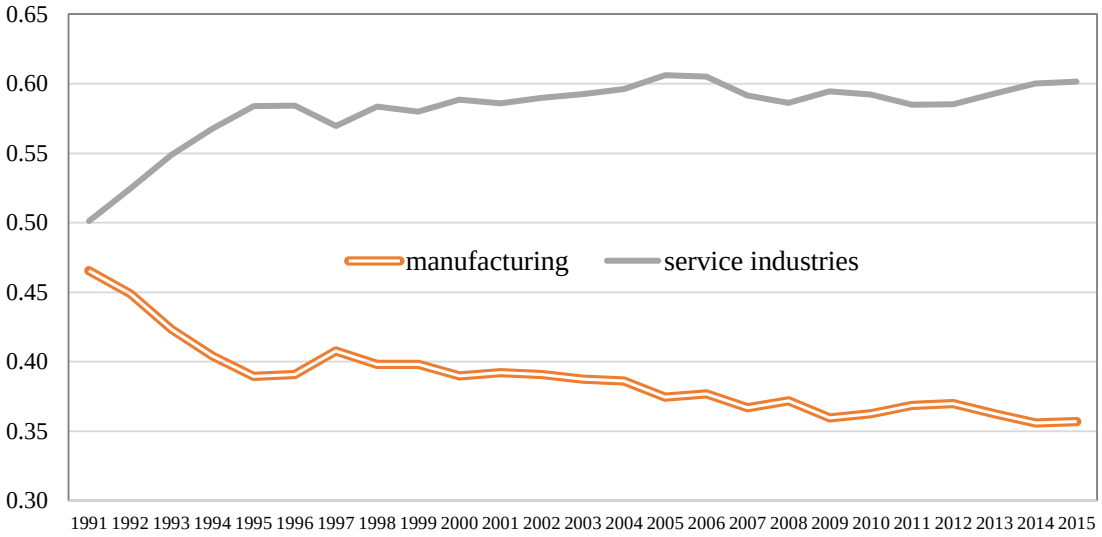
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Figure 10 Employment share by sex: 1991-2015



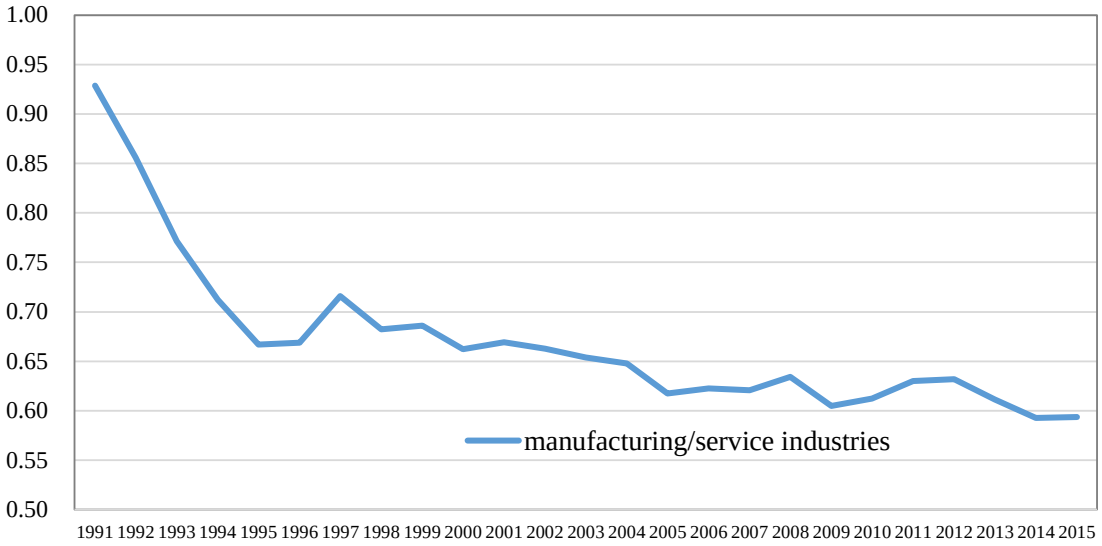
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 11a Employment share by industry: 1991-2015



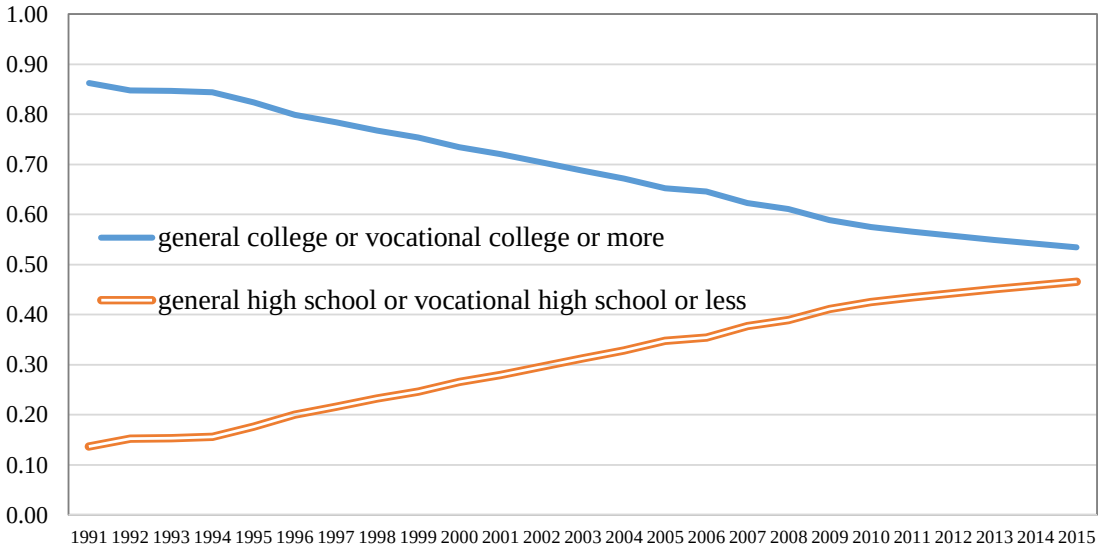
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Figure 11b Employment ratio by industry: 1991-2015



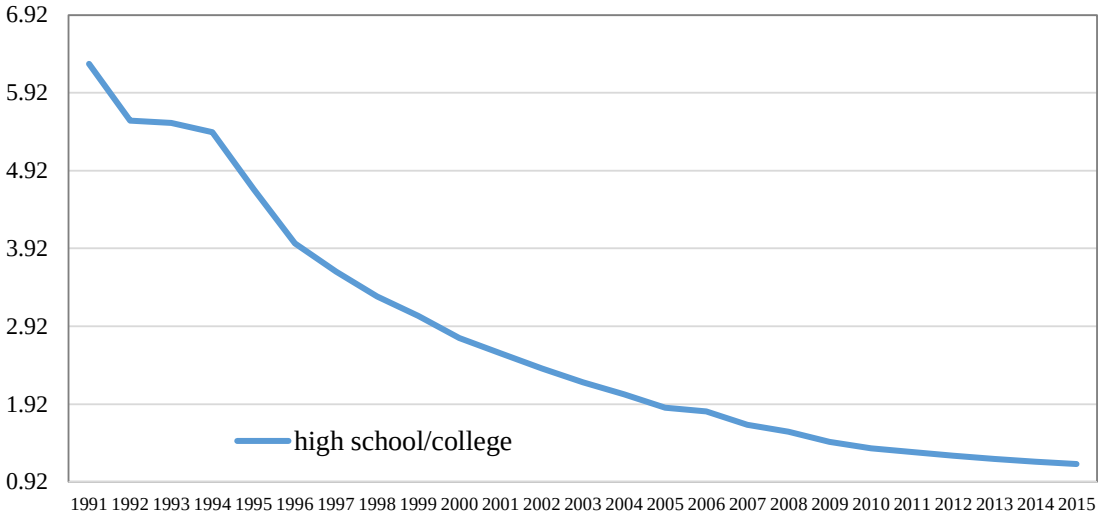
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Figure 12a Employment share by education: 1991-2015



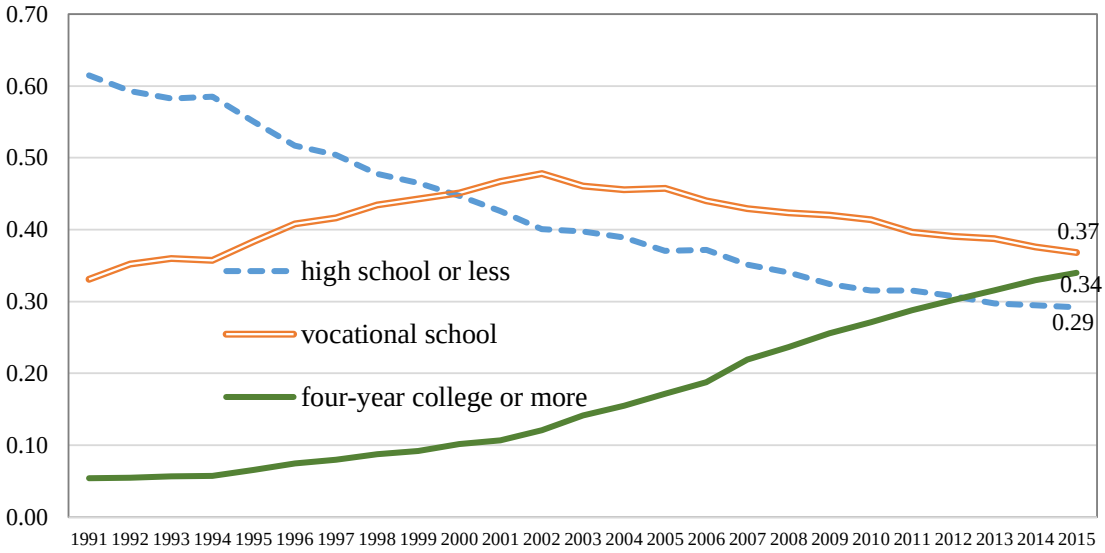
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Figure 12b Employment ratio by education: 1991-2015



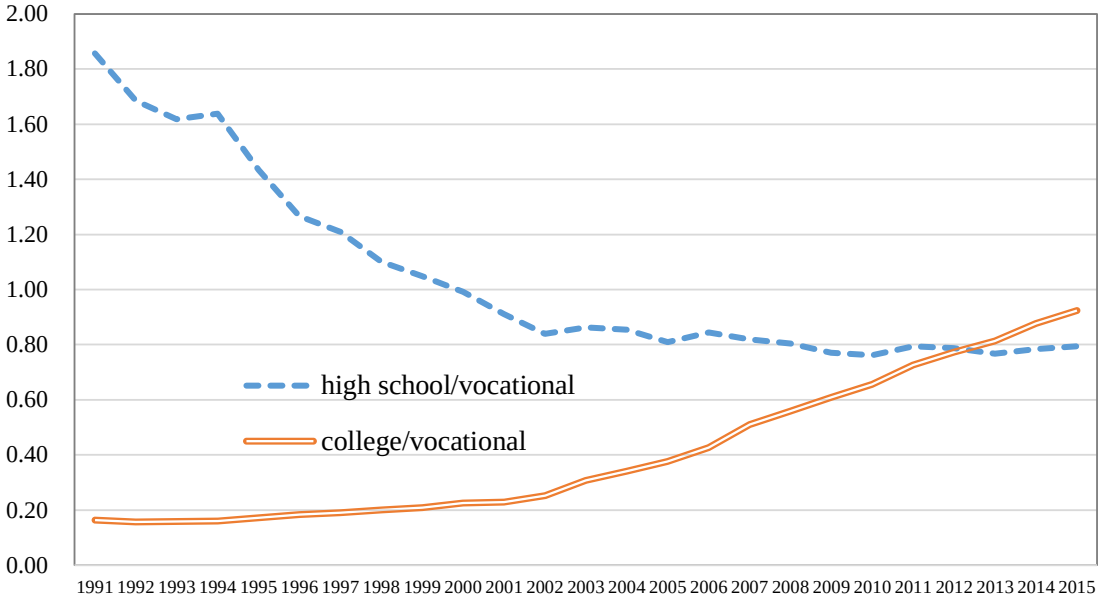
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Figure 13a Employment share by education: 1991-2015



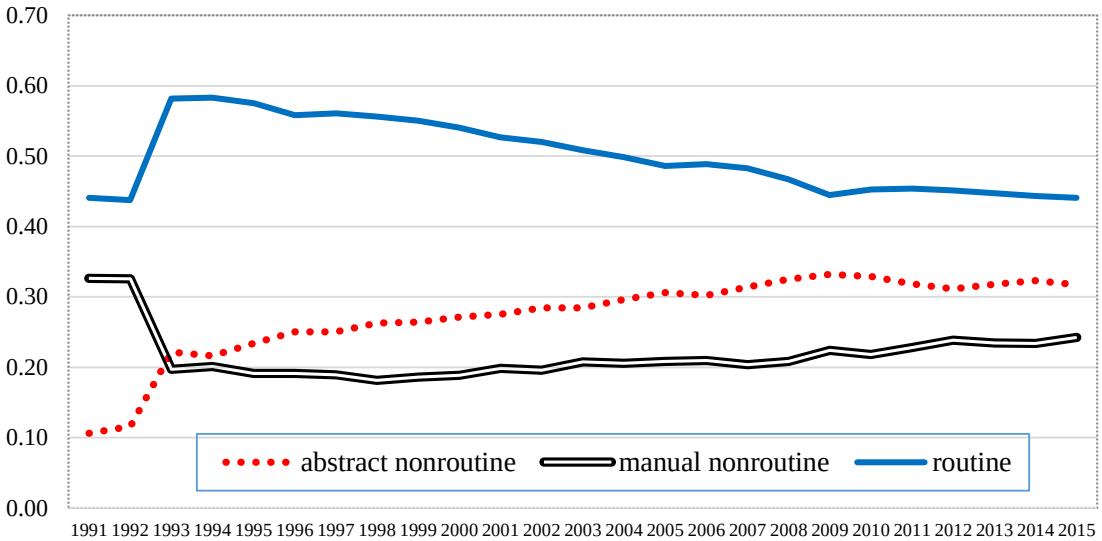
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Figure 13b Employment ratio by education: 1991-2015



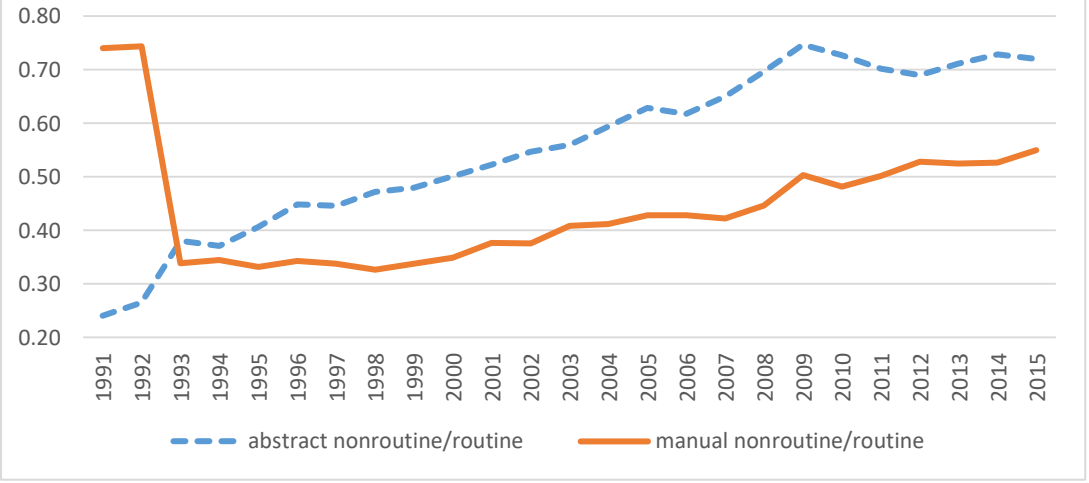
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 14a Employment share by occupation: 1991-2015



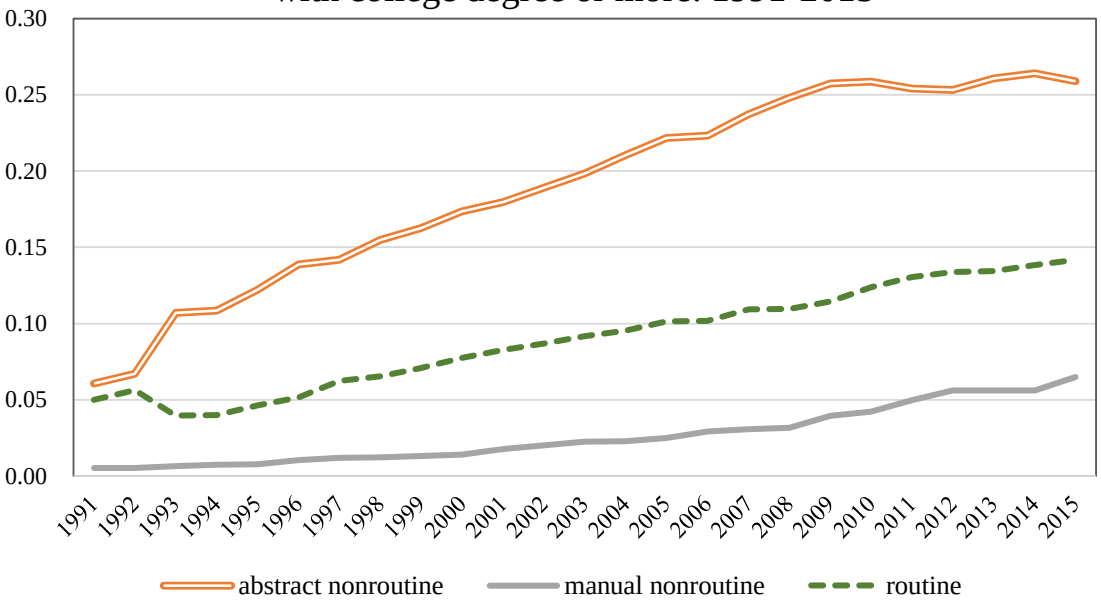
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 14b Employment ratio by occupation: 1991-2015



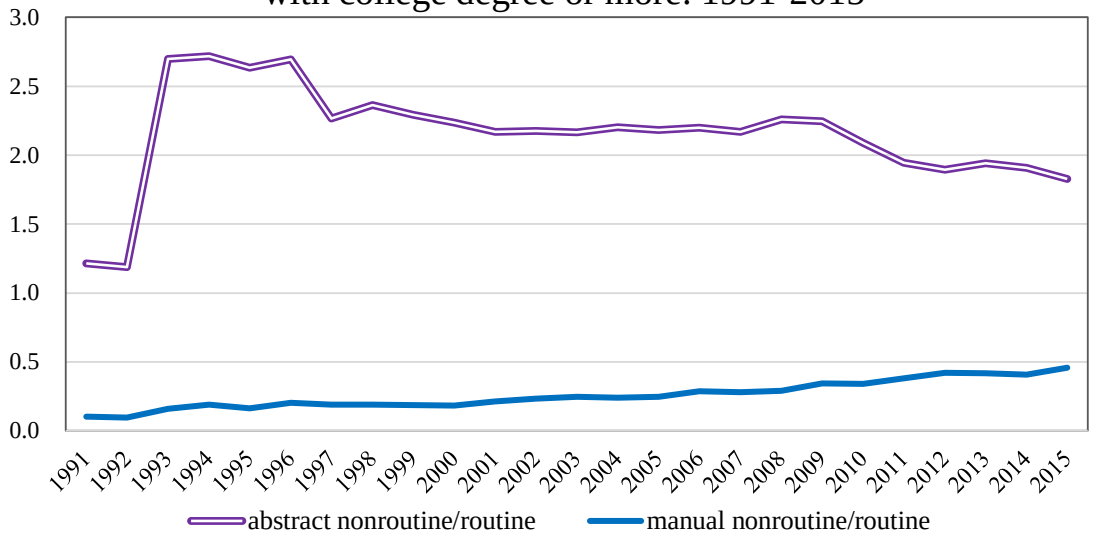
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 15a Employment share by occupation of workers with college degree or more: 1991-2015



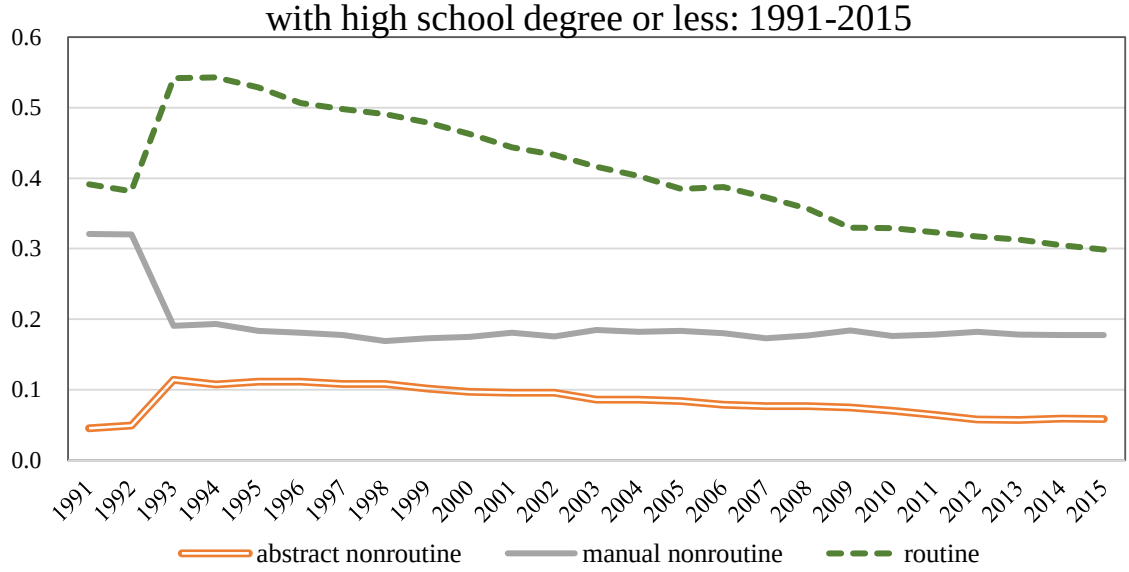
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 15b Employment ratio by occupation of workers with college degree or more: 1991-2015



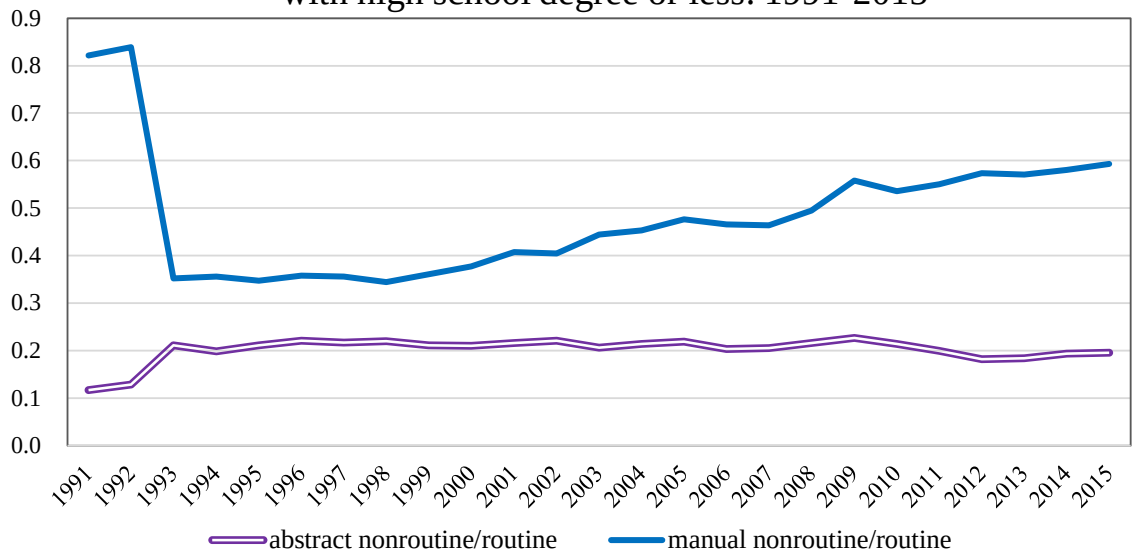
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 16a Employment share by occupation of workers with high school degree or less: 1991-2015



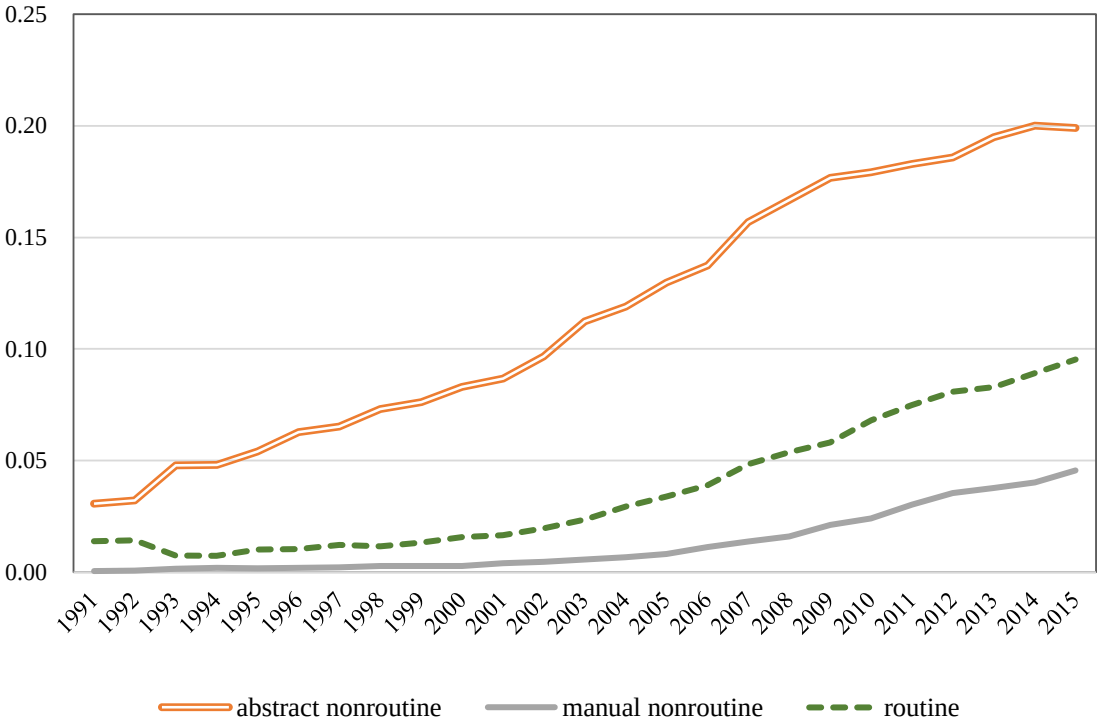
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 16b Employment ratio by occupation of workers with high school degree or less: 1991-2015



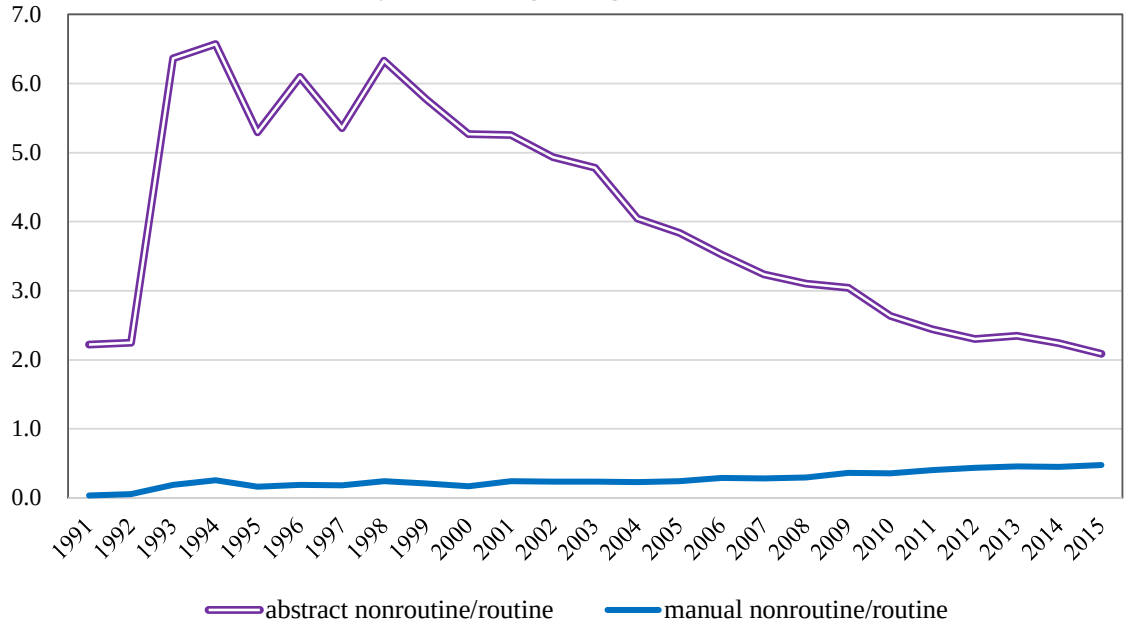
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 17a Employment share by occupation of workers with four-year-college degree or more: 1991-2015



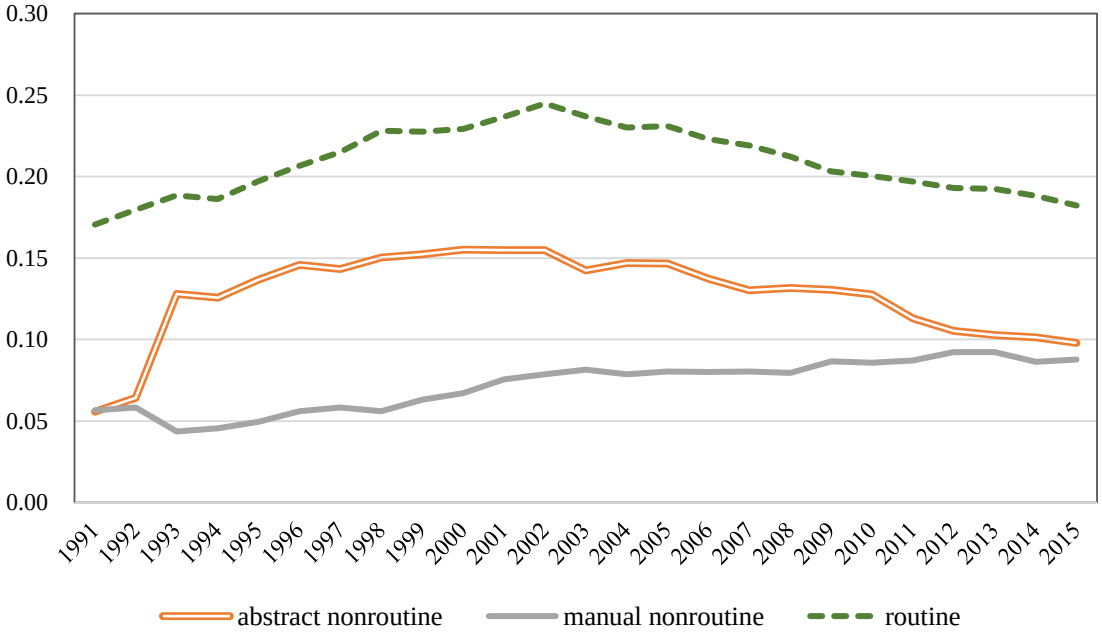
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 17b Employment ratio by occupation of workers with four-year-college degree or more: 1991-2015



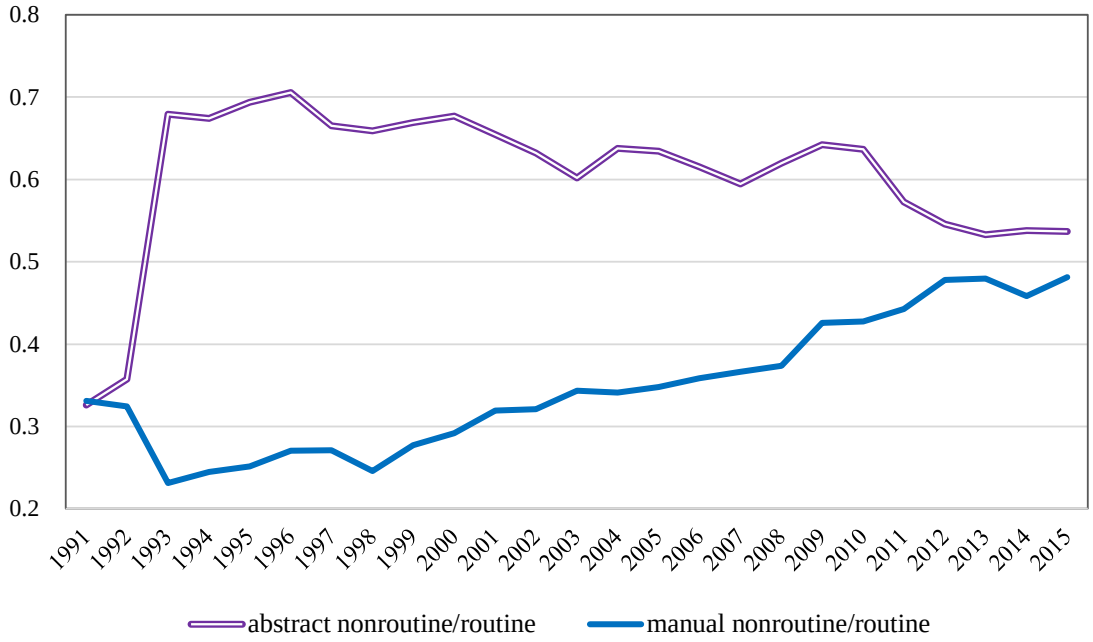
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 18a Employment share by occupation of workers with vocational degree: 1991-2015



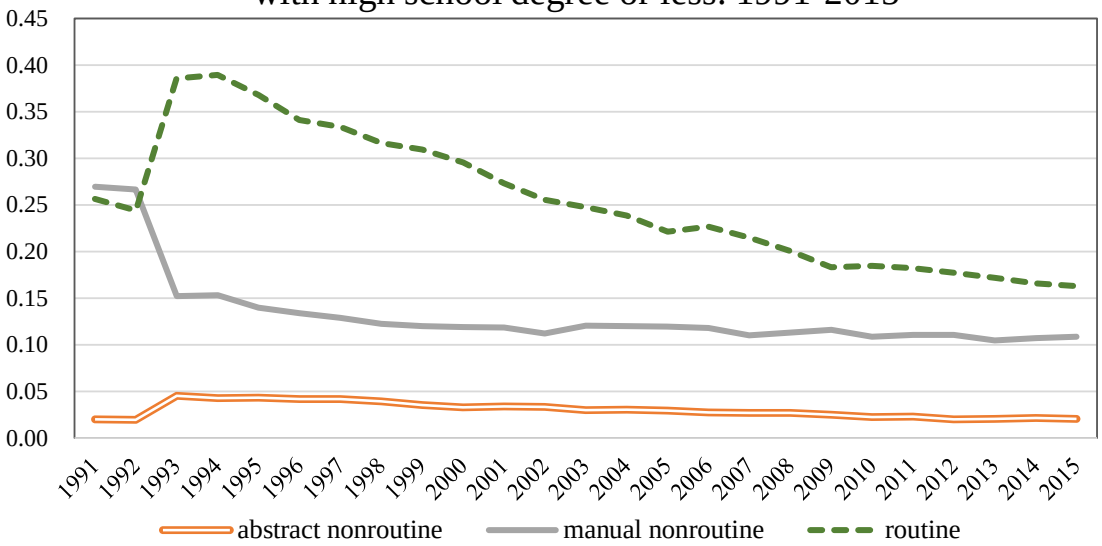
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 18b Employment ratio by occupation of workers with vocational degree: 1991-2015



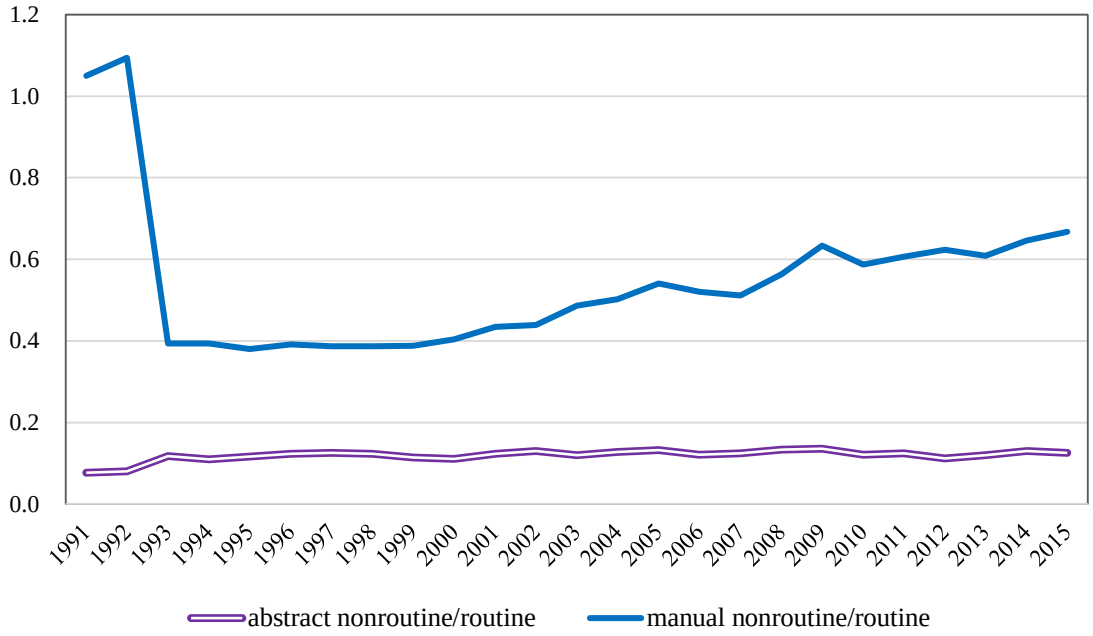
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 19a Employment share by occupation of workers with high school degree or less: 1991-2015



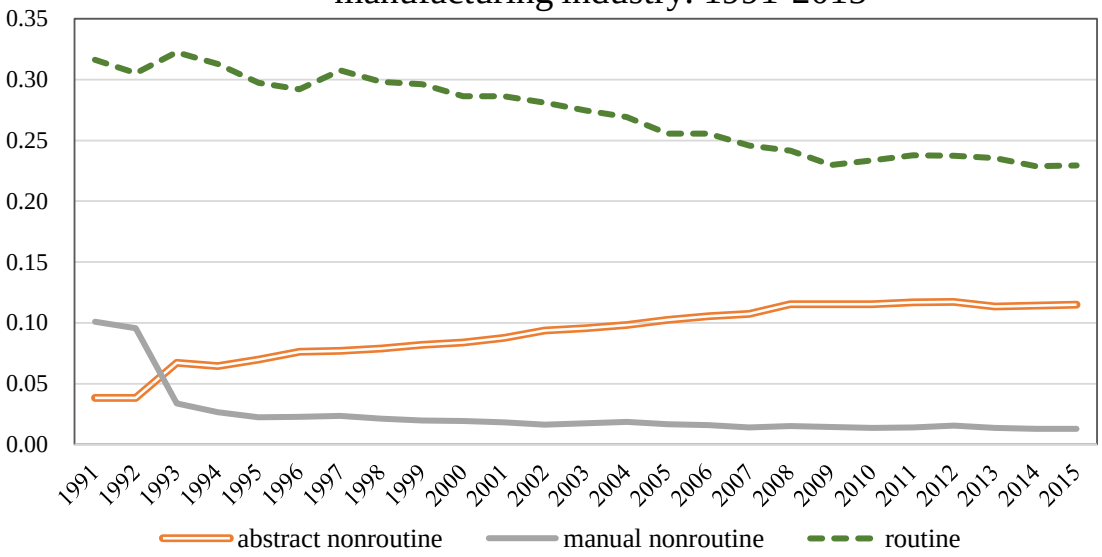
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 19b Employment ratio by occupation of workers with high school degree or less: 1991-2015



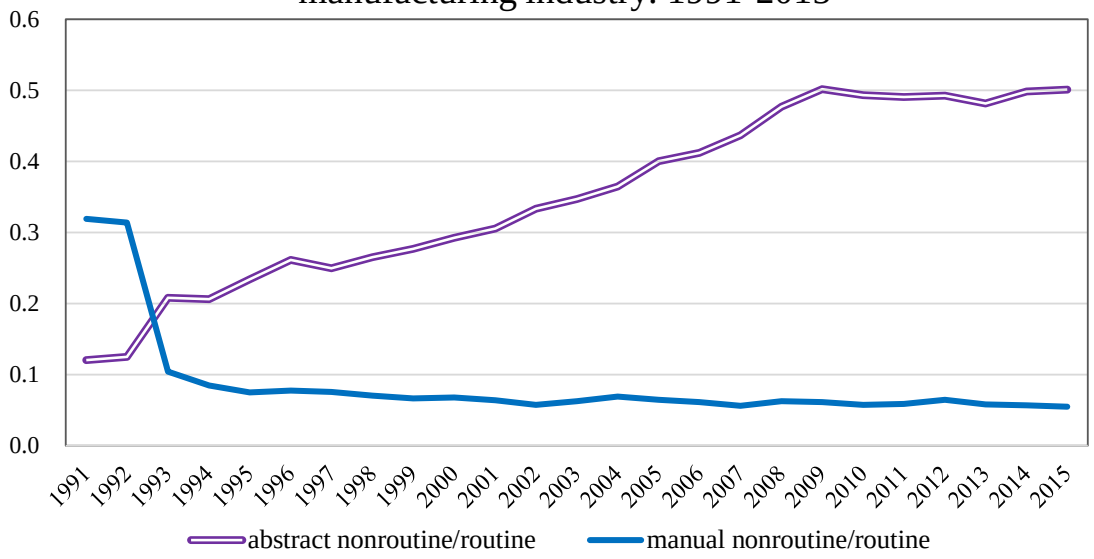
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 20a Employment share by occupation in manufacturing industry: 1991-2015



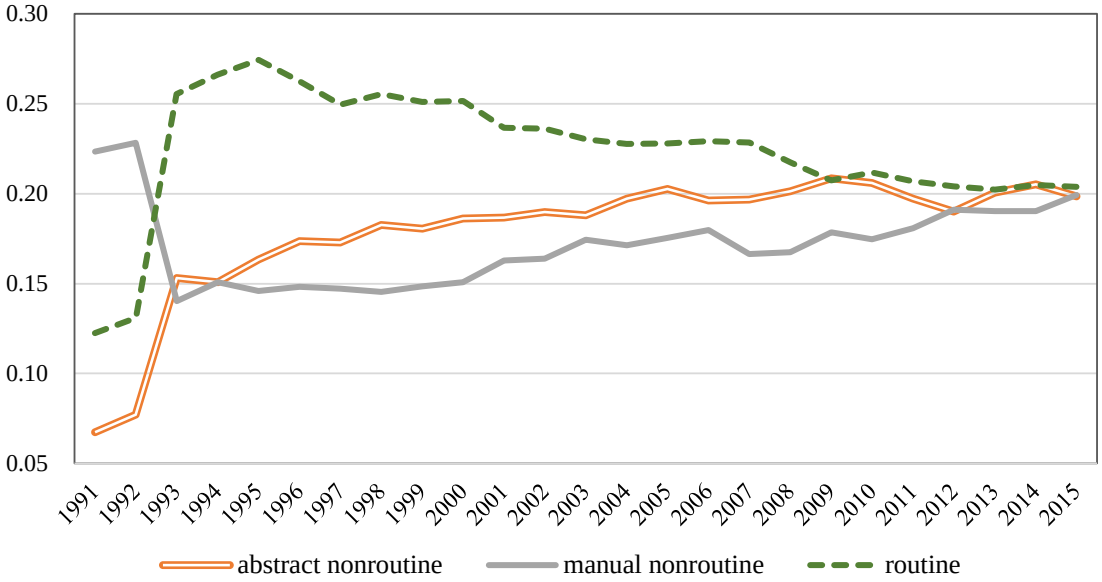
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 20b Employment ratio by occupation in manufacturing industry: 1991-2015



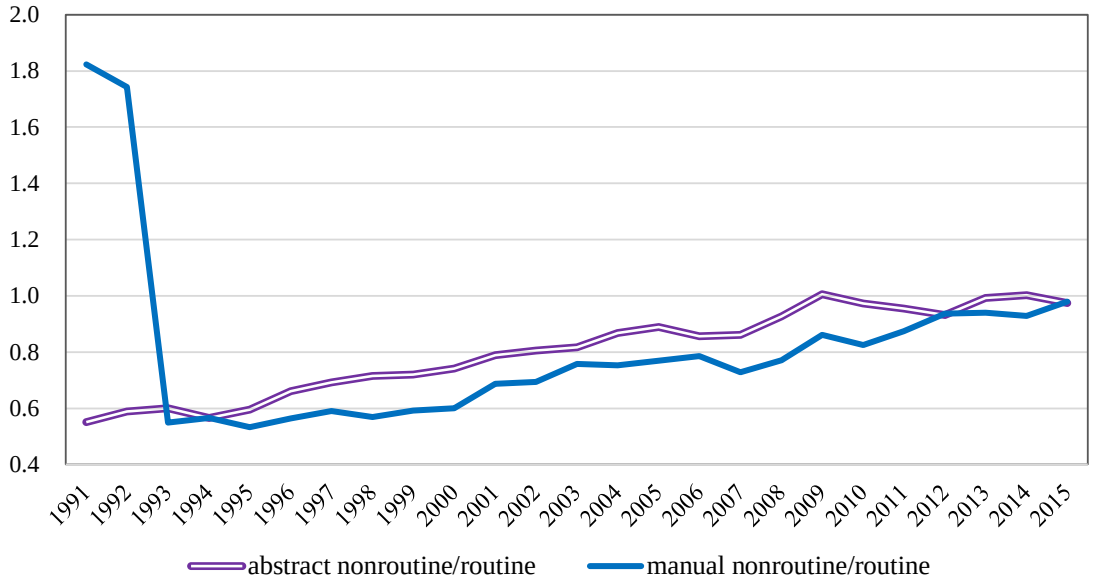
Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 21a Employment share by occupation in service industries: 1991-2015



Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.

Figure 21b Employment ratio by occupation in service industries: 1991-2015



Source: The Manpower Survey (MS) and the Manpower Utilization Survey (MUS), 1991-2015, Directorate General of Budget, Accounting and Statistics (DGBAS), Taiwan.