FEATURE ARTICLE

SINGAPORE'S MISSING CAPITAL: ARE LOW-SKILLED FOREIGN WORKERS SUBSTITUTES FOR MACHINERY?

SINGAPORE'S MISSING CAPITAL: ARE LOW-SKILLED FOREIGN WORKERS SUBSTITUTES FOR MACHINERY? [1]

EXECUTIVE SUMMARY

- This study finds that low-skilled foreign workers (FWs) were used as substitutes for machinery in the manufacturing sector during the recent period of FW policy liberalisation from 2003 to 2008. Over this period, the increase in employment of low-skilled FWs had caused manufacturing firms to reduce their machinery intensity. This would in turn have likely dampened the firms' productivity growth.
- Smaller manufacturing firms were found to be more prone to this substitution effect, having lowered their machinery intensity by twice as much as the average firm for a given increase in their ratio of low-skilled FWs.
- While low-skilled FWs were found to be substitutes to machinery, their overall impact on manufacturing firms' machinery intensity over the period of 2003 to 2008 was small. This suggests that apart from tightening FW policies to boost machinery intensity and hence productivity, other measures to improve productivity, such as helping firms to focus on R&D and product innovation, are also necessary.

The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Ministry of Trade and Industry or the Government of Singapore.

INTRODUCTION

As a resource-scarce country in a fast-growing region, Singapore faces several supply-side constraints to its economic growth, the chief of these being labour constraints. The Total Fertility Rate (TFR) of Singapore citizens has been below replacement rate for more than three decades and this 'baby deficit', coupled with longer life expectancies, has resulted in an ageing and shrinking citizen population. Consequently, the citizen workforce growth has declined and is expected to stagnate beyond 2020.

Historically, the government had turned to permanent and transient immigrant workers to augment the citizen workforce and support economic growth. The most recent period of foreign worker (FW) policy liberalisation was between 2003 and 2008, when the dependency ratio ceiling (DRC) was raised to 65 per cent, levies for unskilled Work Permit Holders (WPH) were reduced and firms were allowed to hire WPHs from the People's Republic of China.

While access to FWs helps to lower costs for firms and boost economic growth, the conventional wisdom is that easy access to cheap, low-skilled FWs also discourages firms from investing in automation and capital, which would in turn dampen their productivity growth. [2] This is especially since aggregate statistics for the manufacturing sector show that the employment of FWs had increased between 2003 and 2008, whereas machinery per worker had declined. As many factors could have affected both machinery investment and the hiring of FWs concurrently, this study attempts to examine whether there is indeed a causal relationship between the employment of low-skilled FWs and machinery intensity among firms in the manufacturing sector.

The rest of the article is organised as follows. The next section covers a review of the literature on the substitutability between low-skilled workers and capital. Thereafter, we describe the methodology and data used for the study, before presenting our results and discussing the implications of our findings. The final section concludes.

[1] We would like to thank Jessica Pan, Thia Jang Ping and Yong Yik Wei for their inputs in our study. All errors belong to the authors.
[2] See for instance Terauds (2011) and Low et al (2013).

LITERATURE REVIEW

The literature on the relationship between workers and capital is focused on the impact of skills-biased technological change. Economists generally believe that technological changes like the advent of computers have boosted the employment and earnings of skilled workers, and led to a substitution away from less skilled workers (e.g., clerical workers).[3] While many researchers have attempted to ascertain the causal impact of technological change on workers, less work has been done on testing the causal relationship between low-skilled workers and the adoption of technology.

Lewis (2011) tested this relationship by exploiting the differences in low-skilled immigrant inflows (and hence low-skilled labour supply) in various metropolitan areas in the US. He argues that these immigration patterns were driven by the tendency of immigrants to congregate in areas with historically large bases of immigrants, and hence were independent of the economic conditions in these areas.[4] This then allowed him to conclude that an increase in the supply of low-skilled workers caused (i) a slower adoption of advanced technology; and (ii) a decline in capital intensity (capital stock per worker) among manufacturing firms in the US.

METHODOLOGY AND DATA

We estimate the causal effect of changes in the relative employment of low-skilled FWs on manufacturing firms' machinery intensity in Singapore over the period of 2003 to 2008 (the recent period of FW liberalisation in Singapore).[5] Our econometric model is based on Lewis (2011), except that we examine a subset of low-skilled workers (i.e. low-skilled FWs). Our regression specification is as follows:[6]

$$\ln\left(\Delta\frac{K_M}{L+H}\right)_i = \beta_0 + \beta_1\left(\Delta\frac{L_F}{H}\right)_i + \beta_v X_i + \varepsilon_i$$

Where:

Δ — Change over the period of 2003 to 2008
i — A firm in our sample
K_M — Net book value of machinery, in dollars
H — Number of high-skilled production workers, defined as workers with a diploma[7]
L — Number of low-skilled production workers, defined as workers with qualifications below a diploma
L_F — Number of low-skilled FWs, defined as FWs with qualifications below a diploma
X — Other firm level variables such as revenue (see Annex A for full list of variables)

However, running a simple regression of machinery intensity on low-skilled FW intensity leads to two key biases that prevent a causal interpretation:

i. Omitted variable bias: In a simple regression, we can only control for factors that firms report such as revenue and export intensity. However, there are factors that affect both machinery intensity and the hiring of FWs which firms do not report. For instance, managerial quality and innovation, which we cannot measure, affect both investment decisions (and thus machinery intensity) and the choice of workers that a firm hires. By excluding these unobserved variables, the coefficient for the ratio of low-skilled FWs could end up picking up the effect of managerial quality and innovation on machinery

[3] See for instance, Krueger (1993) and Goos et al (2010).
[4] If immigrants were attracted by favourable economic conditions, and we expect capital investments to be affected by these conditions as well, then we cannot tell if the relationship between immigrants and capital investment is a causal one or a correlation induced by economic conditions.
[5] We are unable to extend the period of the study beyond 2009 due to data limitations. Specifically, the educational profile of workers - which we use to define skills - is unavailable in the dataset after 2009. We also exclude 2009 from the study due to the recession caused by the Global Financial Crisis.
[6] Note that this is a first-difference model, and as such, would also control for different characteristics across firms that are time invariant.
[7] This definition is similar to Lewis' model. His model excludes workers with a degree because they are usually non-production workers (managers etc.) and hence should not be correlated with machinery investments.

intensity as well, leading to a biased result. For example, if poor management quality leads to both lower machinery intensity and a higher ratio of low-skilled FWs, a negative coefficient for the ratio of low-skilled FWs may be due to management quality rather than the increased employment of low-skilled FWs.

ii. Reverse causality: While increases in the employment of low-skilled FWs could affect investments in machinery, the reverse might also be true. For example, (i) some firms which invest in modern machinery might require certain types of FWs to operate them; or (ii) firms which invest in more machines could hire less FWs because their processes are less labour intensive. If reverse causality is present, it would be difficult to determine whether and to what extent changes in the employment of low-skilled FWs caused changes in machinery intensity.

To deal with these two issues, we employ two econometric techniques that are widely used in the academic literature:

i. Olley and Pakes's (1996) technique to correct for omitted variable bias: While we are not able to observe factors like managerial quality, these factors have been found to affect firms' investment decisions. For instance, we may expect good managers to purchase more machinery and non-machinery types of capital. As such, we may use firms' investment behaviour, which we observe, to proxy for managerial quality and other unobserved factors. In our study, we use a polynomial of the change in firm-level investments in non-machinery capital (ΔI_O) and non-machinery capital stock (ΔK_O) as a proxy (henceforth Olley-Pakes), in line with the academic literature:[8]

$$\ln\left(\Delta\frac{K_M}{L+H}\right)_i = \beta_0 + \beta_1\left(\Delta\frac{L_F}{H}\right)_i + \beta_v X_i + f(\Delta I_{O_i}, \Delta K_{O_i}) + \varepsilon_i$$

ii. Instrumental Variable (IV) to correct for reverse causality: This technique requires an additional variable which affects the employment of low-skilled FWs, but does not affect machinery intensity, except through the employment of low-skilled FWs. In our study, we use the dependency ratio (DR) of individual firms in 2001 as the IV. Firms with a higher DR in 2001 would be less able to hire low-skilled FWs from 2003 to 2008 because (i) they were closer to the DRC and hence had a smaller usable FW quota; and (ii) as levies are tiered, their cost per FW would likely be higher as compared to firms with a lower DR. At the same time, we do not expect the initial DR in 2001 to directly affect firms' machinery investment from 2003 to 2008.[9] Specifically, we run the following IV regression:

$$\left(\Delta\frac{L_F}{H}\right)_i = \gamma_0 + \gamma_1 DR_{2001_i} + \gamma_v X_i + f(\Delta I_{O_i}, \Delta K_{O_i}) + v_i \text{ (First stage)}$$

$$\ln\left(\Delta\frac{K_M}{L+H}\right)_i = \beta_0 + \beta_1\left(\widehat{\Delta\frac{L_F}{H}}\right)_i + \beta_v X_i + f(\Delta I_{O_i}, \Delta K_{O_i}) + \varepsilon_i \text{ (Second stage)}$$

where $\left(\widehat{\Delta\frac{L_F}{H}}\right)_i$ is the predicted value of $\left(\Delta\frac{L_F}{H}\right)_i$ from the first stage of the regression.

[8] See Olley and Pakes (1996). ΔI_O and ΔK_O are changes in capital investments and stock that exclude machinery. To estimate $f(\Delta I_{O_i}, \Delta K_{O_i})$, we include a four degree polynomial function of ΔI_O and ΔK_O.

[9] This condition is known as the exclusion restriction. For our IV to remove the biases successfully, firms' DRs in 2001 should not affect their machinery investment decisions from 2003-2008 through channels which are not captured in the model. In addition to selecting an IV from two years prior to our sample period, we satisfy the exclusion restriction by separately accounting for other factors that could affect machinery investment decisions. For example, we control for (i) employment structure; (ii) size; (iii) ownership structure, and (iv) firm-level efficiency through the Olley-Pakes proxy. An example of a possible factor that we cannot account for is the interest rate that individual firms face. However, we do not think this is problematic for our IV because (i) several factors that affect firm's interest rates (like size, ownership and efficiency) are captured in our model; and (ii) we do not expect banks to factor in firms' historical employment structure (DR in 2001) to evaluate their current (2003-2008) credit worthiness. To test the robustness of our IV, we also used firms' DR in 2002 and 2003 and obtained similar results.

Our sample of firms for the study was drawn from EDB's annual Census of Manufacturing, which surveys the larger firms (i.e., firms with 20 employees or more) every year. This allows us to create a panel of 1,500 manufacturing firms that existed in 2003 and 2008. Our findings thus apply only to the firms in our sample, which we expect to be (i) larger firms, since small firms may not be surveyed in both years; and (ii) stronger firms, since we have excluded firms that folded between 2003 and 2008.

RESULTS

Our regression results indicate that an increase in the low-skilled FW intensity of a manufacturing firm would lead to a fall in the machinery intensity of the firm (Exhibit 1). This implies that during the period of FW policy liberalisation from 2003 to 2008, low-skilled FWs were substitutes for machinery, thereby discouraging machinery investments. Specifically, after correcting for omitted variable bias and reverse causality, we find that, on average, a 1 unit increase in the ratio of low-skilled FWs would lead to a 9.1 per cent decline in machinery intensity among the manufacturing firms (see specification 3 below).[10]

Exhibit 1: Regression Results for the Impact of Low-Skilled FW Intensity on Machinery Intensity [11,12]

Specification	(1)	(2)	(3)
Dependent Variable	ΔLog(Machinery Intensity)	ΔLog(Machinery Intensity)	ΔLog(Machinery Intensity)
ΔRatio of low-skilled FWs	-.005	-.006	**-.091 ****
ΔRatio of low-skilled locals	-.001	-.001	.051 **
ΔLog(Revenue)	.266 ***	.189 ***	.276 ***
$Log(Revenue_{2003})$	-.109 ***	-.107 ***	-.076 **
$Local\ (dummy)_{2003}$	-.122	-.111	-.067
$SME\ (dummy)_{2003}$	-.402 ***	-.380 ***	-.293 **
Other Controls:			
Constant	Yes	Yes	Yes
Olley-Pakes	No	**Yes**	Yes
Instrumented	No	No	**Yes**
Observations[+]	1,500	1,500	1,347

*** P-value<0.01, ** P-value<0.05, * P-value<0.1

[+]Note: Number of observations differs in specification 3 as 153 firms were not present in the dataset in 2001, and thus could not be instrumented.

We next split our sample of manufacturing firms into revenue terciles to determine if the results differ by firm size. We find a stronger relationship (i.e., greater substitution between low-skilled FWs and machinery) for the smaller firms in our sample (Exhibit 2). In particular, for firms in the lowest revenue tercile, a 1 unit increase in the ratio of low-skilled FWs is found to lead to a 17 per cent decline in machinery intensity. One possible explanation is that smaller firms tend to utilise simpler production processes and machinery, which are more easily substituted with low-skilled labour.

[10] Before correcting for reverse causality, the magnitude of our coefficient was smaller at -0.006. Taken together, the two estimated coefficients suggest that firms that invested in more machinery hired more low-skilled FWs.

[11] We also carried out several sensitivity checks, and our results are robust to (i) the inclusion of additional labour variables (e.g., employment share of non-production workers); (ii) the exclusion of outliers (e.g., firms with no FWs); and (iii) using the ratio of low-skilled FWs to the total production workforce of a firm as our key variable of interest.

[12] While the coefficient on the ratio of low-skilled local workers was positive and significant, we should not read too much into it as the ratio was used only as a control variable. Nevertheless, one possible explanation is that the coefficient is picking up the positive correlation between movements in machinery intensity and ratio of low-skilled workers among firms in the sample over this period.

Exhibit 2: Regressions Results for the Different Revenue Terciles

Dataset	≤ 33rd Revenue Percentile	33rd < Revenue Percentiles ≤ 66th	> 66th Revenue Percentile
Dependent Variable	ΔLog(Machinery Intensity)	ΔLog(Machinery Intensity)	ΔLog(Machinery Intensity)
ΔRatio of low-skilled FWs	**-.172 *** **	-.001	-.057
ΔRatio of low-skilled locals	.075 **	.001	0.034
ΔLog(Revenue)	.353 **	.138	.245 ***
Log(Revenue$_{2003}$)	-.292	-.437 *	-.015
Local (dummy)$_{2003}$	.063	.018	-.162
Other Controls:			
Constant	Yes	Yes	Yes
Olley-Pakes	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes
Observations[+]	409	460	478

*** P-value<0.01, ** P-value<0.05, * P-value<0.1

[+]Note: Number of observations differs across the terciles as not all firms were present in the dataset in 2001, and thus could not be instrumented.

IMPLICATIONS OF FINDINGS

Finding 1: Low-skilled FWs are substitutes for machinery in manufacturing firms

Our results suggest that low-skilled FWs were substitutes for machinery as the increase in low-skilled FW ratio from 2003 to 2008 had caused manufacturing firms in our sample to reduce their machinery intensity. This implies that continued access to cheap, low-skilled FWs could deter firms from investing in machinery (e.g. for automation). This would, in turn, have likely depressed the productivity of the firms. To help reverse this, the government has already taken steps to reduce firms' reliance on low-skilled FWs. For instance, the DRC for manufacturing was lowered from 65 per cent to 60 per cent in July 2012 and levy rates for WPHshave been raised every year since July 2010.

Finding 2: However, the actual impact of the substitution effect on machinery intensity and hence productivity is likely to have been small

Although low-skilled FWs were substitutes for machinery, the overall impact of such substitution could be small. To estimate the actual impact of such substitution between 2003 and 2008, we apply our estimated coefficient for the low-skilled FW ratio to the actual change in the average low-skilled FW ratio among the firms in our sample.[13] We find that the increase in the ratio of low-skilled FWs (at around 0.1) had led to a decline in machinery intensity of less than 1 per cent (Exhibit 3).[14] Even for firms in the lowest revenue tercile, which experienced the greatest substitution between low-skilled FWs and machinery, the increase in low-skilled FW intensity had led to a marginal decline in machinery intensity of about 1.2 per cent.

Given that the machinery intensity of firms in our sample declined by a much larger 10 per cent between 2003 and 2008, our simulation results suggest that non-FW related factors could also be affecting the machinery intensity of these firms. One possibility is the increasing servitisation of manufacturing, which

[13] We use the coefficient for specification 3, from Exhibit 2, to estimate the impact for all firms. We multiply the coefficient with the actual increase in low-skilled FW ratio for the firms. We similarly estimate the impact for firms in the ≤ 33rd revenue percentile using the relevant coefficient from Exhibit 3.

[14] This is not unexpected as the manufacturing sector in Singapore is fairly advanced and capital intensive—for instance, our electronics sector has moved from assembling hard disk drives (which is something humans can easily do) to producing hard disk media. The latter requires precision that human effort alone cannot achieve. It will be difficult to replicate such manufacturing with labour.

could have depressed the machinery intensity of manufacturing firms as they moved into activities such as consulting, intellectual property and the administration of regional headquarters.[15]

Exhibit 3: Estimated Impact of Low-Skilled FW Intensity on Machinery Intensity

	Impact of Low-Skilled FW Intensity	Change in Ratio Of Low-Skilled FWs	Estimated Change in Machinery Intensity
All Firms	9.1	0.09	**-0.85%**
Firms in Lowest Revenue Tercile	17.2	0.07	**-1.24%**

To the extent that there could be other factors affecting the machinery intensity of firms, our finding also suggests that apart from tightening firms' access to low-skilled FWs to boost machinery intensity and hence productivity, other measures to help firms improve their productivity (e.g., through research and development – or R&D – and product innovation) may also be important.

CONCLUSION

This study finds that the increase in low-skilled FW intensity of manufacturing firms during the period of FW liberalisation between 2003 and 2008 had caused them to reduce their machinery intensity. This implies that FWs were used as substitutes for machinery during this period. In particular, smaller firms were more prone to this substitution effect, having lowered their machinery intensity by twice as much as the average firm for a given increase in their ratio of low-skilled FWs.

The dampening impact of low-skilled FWs on machinery intensity is also likely to have depressed the productivity of manufacturing firms. To help reverse this, the government has already taken steps to reduce firms' reliance on low-skilled FWs. However, our findings also suggest that there are other non-FW related factors affecting the machinery intensity and hence productivity of firms. Accordingly, other measures to increase the productivity of manufacturing firms, such as helping them to focus on R&D and product innovation, are also necessary.

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[15] For instance, Professor Andy Neely found that more than 40 per cent of manufacturing companies in Singapore have servitised as of 2007. This is the third highest level when compared to other manufacturing intensive economies like Germany, Switzerland and Taiwan (accessed through http://opim.wharton.upenn.edu/fdecon/presentations/DAY%201%20AM/PANEL%201/Neely%20110228-WhartonForum.pdf).

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ANNEX A

Firm-Level Control Variables
Revenue levels, 2003, Singapore dollars
Change in revenue from 2003 to 2008, Singapore dollars
Change in the employment ratio of low-skilled local workers to high-skilled workers
Dummy for whether firm was an SME in 2003[16]
Dummy for whether >50% of the firm was owned by locals in 2003

[16] We use SPRING's definition of SMEs: firms' annual sales turnover of not more than $100 million or employment size not more than 200 workers.