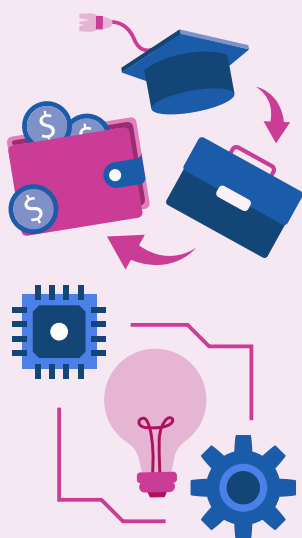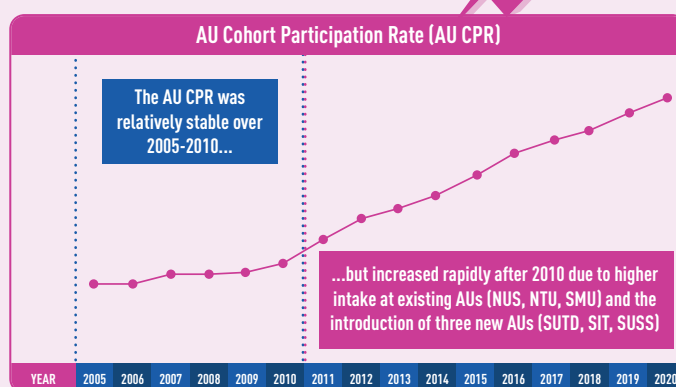**Feature Article**

INCREASES IN AUTONOMOUS UNIVERSITY COHORT PARTICIPATION RATE AND THE LABOUR MARKET

OVERVIEW

The Autonomous University Cohort Participation Rate (AU CPR) has risen since 2011, contributing to an increase in the intake of students in Singapore's AUs, and a rise in the supply of university graduates relative to other groups in the labour market. This could reduce the relative wage of university graduates unless relative demand also rose concurrently.

To better understand whether the rise in relative supply of university graduates was matched by an increase in relative demand, this article examines how the relative wage of university graduates changed with the increase in AU CPR between 2011 and 2016, and delves into possible mechanisms behind the findings.

AU Cohort Participation Rate (AU CPR)

The AU CPR was relatively stable over 2005-2010...

...but increased rapidly after 2010 due to higher intake at existing AUs (NUS, NTU, SMU) and the introduction of three new AUs (SUTD, SIT, SUSS)

YEAR 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

FINDINGS

Finding 1:
Our main regression analysis showed that the composition-adjusted relative wage of university graduates remained stable even as AU intake rose between 2011 and 2016. This suggests that there was a concurrent increase in relative demand for university graduates that matched the rise in relative supply.

Finding 2:
Using relative demand regressions, we found evidence that the increase in relative demand was primarily due to exogenous demand shifts (e.g., secular increases in demand for university graduates from skill-intensive sectors), as well as endogenous demand increases due to technological choice (i.e., sectors shifting towards existing skill-intensive technologies because of a rise in the relative supply of university graduates, which in turn raised the relative demand for university graduates).

POLICY TAKEAWAY

The increase in the relative supply of university graduates arising from the 2011 – 2016 AU CPR increases was matched by a rise in the relative demand for these graduates.

These findings are encouraging and suggest that our economic agencies have been successful in anchoring firms and skilled jobs in Singapore, and that our AUs have been able to nurture a skilled workforce that is able to compete successfully for and perform well in these jobs.

MOE will continue working with MTI, MOM and other economic agencies to support AUs in equipping students with the necessary skills to take on good jobs in the economy, and closely monitor the labour market outcomes of all students amid the planned increase in AU CPR announced in March 2023.
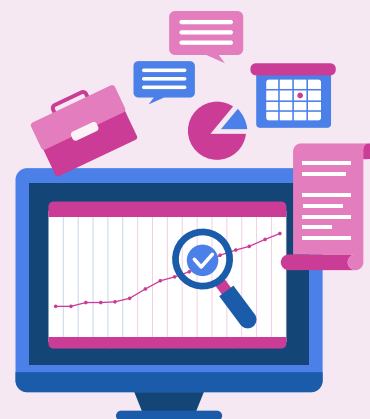
EXECUTIVE SUMMARY

- The Autonomous University Cohort Participation Rate (AU CPR) has risen since 2011, contributing to an increase in the intake of students in Singapore's AUs, and consequently, a rise in the supply of university graduates relative to other educational groups in the labour market. Economic theory predicts that an increase in the relative supply of university graduates could lead to a fall in their relative wage unless the relative demand for them also rises concurrently.

- To better understand whether the rise in the relative supply of university graduates was matched by an increase in relative demand, this article examines how the relative wage of university graduates changed with the increase in AU CPR between 2011 and 2016. It also delves into the possible mechanisms that drove these findings.

- Using fixed-effects regression analysis (which controlled for students' characteristics), we found that the composition-adjusted relative wage of university graduates remained stable even as AU intake rose between 2011 and 2016. This suggests that there was a concurrent increase in the relative demand for university graduates that matched the rise in the relative supply of university graduates.

- Based on theoretically-motivated relative demand regressions, we found evidence that the increase in relative demand for university graduates was primarily due to exogenous demand shifts (e.g., secular increases in demand for university graduates from skill-intensive sectors). At the same time, there was some suggestive evidence that endogenous demand increases due to technological choice (i.e., sectors shifting towards existing skill-intensive technologies because of a rise in the relative supply of university graduates, which in turn raised the relative demand for university graduates) could have contributed to some extent too.

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.[1]

INTRODUCTION

Singapore's Autonomous Universities (AUs) are funded by the Ministry of Education (MOE). They provide both pre-employment training such as undergraduate education for fresh school leavers, as well as Continuing Education & Training programmes for adult learners. Both types of programmes aim to support individuals in their pursuit of lifelong learning and prepare them for the workforce and industry needs.

The AU intake each year is planned based on the AU Cohort Participation Rate (AU CPR). MOE works with MOM, MTI and other economic agencies to review the AU CPR regularly to take into account Singapore's additional manpower needs across the economy in the medium term, while ensuring good employment prospects for our university graduates. Changes to the AU CPR are calibrated based on the labour market outcomes of past AU graduates and the anticipated industry demand for AU graduates.

Between 2005 and 2010, the AU CPR was stable, and ranged from 24 per cent to 26 per cent. The AU CPR was raised to 28 per cent in 2011, and further raised over the years to reach 40 per cent in 2020. This was accomplished via intake expansions at the existing AUs, including National University of Singapore (NUS), Nanyang Technological University (NTU) and Singapore Management University (SMU), as well as the introduction of three new AUs, namely Singapore University of Technology and Design (SUTD), Singapore Institute of Technology (SIT) and Singapore University of Social Sciences (SUSS), which diversified the university landscape and established new pathways.

Given that the increase in AU CPR would have raised the relative supply of university graduates in the labour market, economic theory predicts that the relative wage of university graduates could fall unless there was a concurrent increase in the relative demand for such graduates.

Against this backdrop, our study examined if the increase in relative supply of university graduates arising from the AU CPR increases from 2011 to 2016[2] was matched by a rise in relative demand for university graduates, by analysing the impact of AU expansions on the relative wage of university graduates. Our study also delved into the possible mechanisms that drove these findings. For the rest of this article, the terms "relative demand/supply" and "demand/supply" will be used interchangeably.

AU CPR INCREASES AND GRADUATE LABOUR MARKET OUTCOMES: THEORY AND EVIDENCE FROM THE ECONOMICS LITERATURE

The economics literature (e.g., Katz & Murphy, 1992; Card & Lemieux, 2001; Blundell et al., 2022) uses variants of a relative demand and supply framework to understand how changes in the supply of university graduates may affect the labour market. This framework accounts for the fact that different groups of workers may substitute or complement one another in the labour market to varying degrees, which in turn implies that large shifts in the supply of one group of workers could have an effect on their own wages as well as the wages of the other groups.

Based on this framework, AU CPR increases will raise the relative supply of university graduates (i.e., supply compared to other groups of workers). As university graduates are likely to be imperfect substitutes for other workers in the labour market, the increase in relative supply of university graduates may result in firms paying the university graduates less, thereby lowering their relative wage (i.e., wage compared to other groups of workers), if there is no change in the relative demand for university graduates (Exhibit 1a).

However, concurrent increases in the relative demand for university graduates may mitigate the negative impact of the increase in relative supply of university graduates on their relative wage. Changes in relative demand may occur through the following channels:

- <u>Exogenous relative demand shifts</u>. These changes in relative demand occur **independently** of changes in the relative supply of university graduates. They may arise from the widespread adoption of skill-intensive technologies, an expansion of existing skill-intensive sectors or the opening up of new skill-intensive product markets, possibly as a result of government investment.

- <u>Endogenous technological choice</u>. This may occur if the increase in relative supply of university graduates **causes** firms to shift towards *existing* skill-intensive technologies, which in turn raises the relative demand for university graduates.

- <u>Endogenous innovation</u>. This may occur if the increase in relative supply of university graduates incentivises the *invention* of skill-intensive technologies, which in turn raises the relative demand for university graduates.

If the relative demand for university graduates increases to match or exceed the rise in relative supply of university graduates, the relative wage of university graduates may remain stable or even increase (Exhibit 1b).

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2 *We focused on the AU CPR increases between 2011 and 2016 (from 28 per cent to 36 per cent) as most students entering AUs in later years would not have entered the labour market at the time of our analysis.*

Exhibit 1: Theoretical impact of changes in relative demand (D) and supply (S) on the relative wage (w) of university graduates

Exhibit 1a: Only relative supply increases

Exhibit 1b: Relative demand and supply both increase
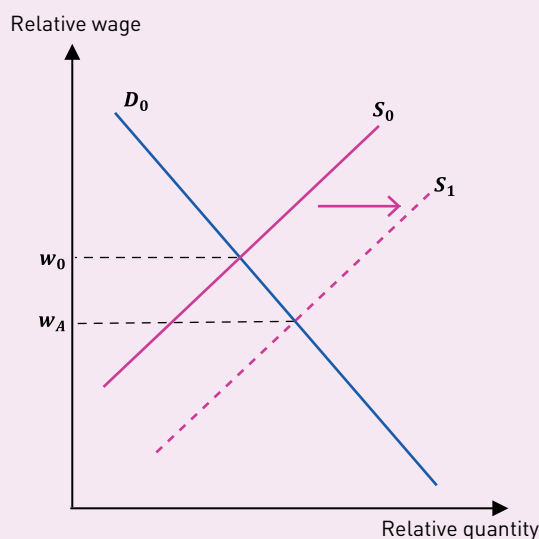
- An increase in university intake raises the relative supply of university graduates ($S_0 \rightarrow S_1$).

- This exerts downward pressure on their relative wage ($w_0 \rightarrow w_A$) if relative demand for university graduates remains unchanged (D_0).
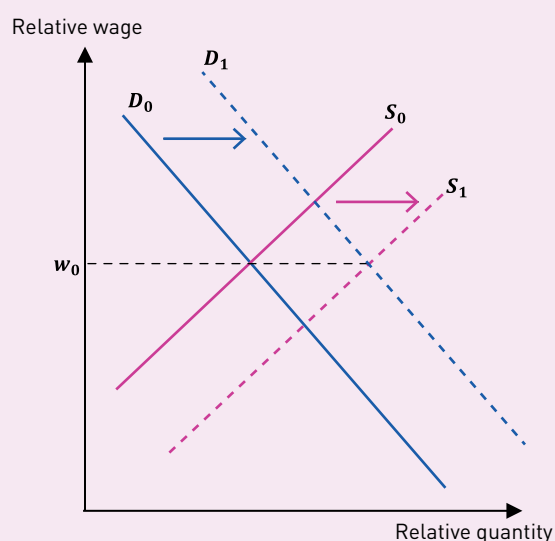
- An increase in relative demand for university graduates through the channels outlined above ($D_0 \rightarrow D_1$) can mitigate the supply-driven downward pressure on relative wage.

- In such cases, relative wage may remain stable or even increase ($\geq w_0$) even though the relative supply of university graduates has increased.

Empirical evidence from the economics literature suggests that the relative demand and supply framework is able to predict the relative wage changes of university graduates when their supply increases well, and that it is possible for relative demand to shift sufficiently to fully match the increase in relative supply of university graduates.

For example, Katz & Murphy (1992) found that a parsimonious model incorporating exogenous relative demand shifts and changes in the relative supply of university graduates predicted changes in the relative wage of university graduates in the US well (Exhibit 2a). In addition, Blundell et al. (2022) found that the relative wage of university graduates in the UK remained stable despite an increase in the relative supply of university graduates over the same period (Exhibit 2b). The authors found some evidence to suggest that the stability in relative wage could have been the result of a shift towards more decentralised processes (e.g., with more employee autonomy) that in turn raised the demand for more educated workers.

Exhibit 2: Empirical evidence from the economics literature

Exhibit 2a: Chart from Katz & Murphy (1992)

Predicted relative wages from a relative demand-supply model tracked actual relative wage changes well.
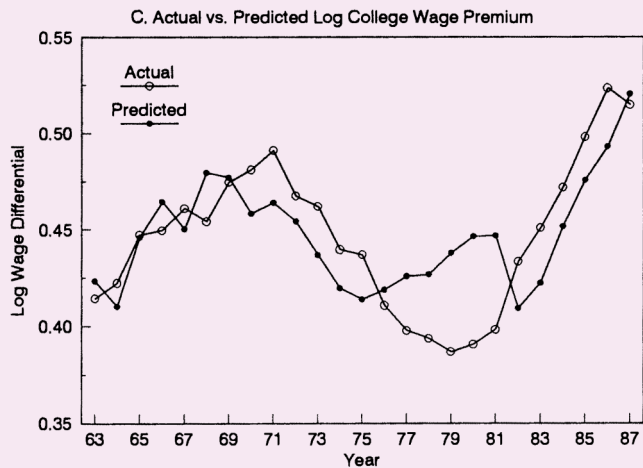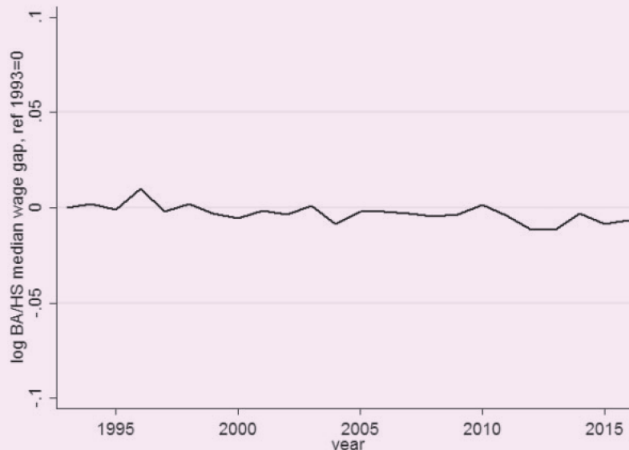
Exhibit 2b: Chart from Blundell et al. (2022)

Relative wage of UK university graduates remained stable despite a rise in the relative supply of university graduates.

IMPACT OF AU CPR INCREASES ON RELATIVE WAGES IN SINGAPORE

In this section, we first examined economy-wide summary statistics on the wages of resident workers from the Comprehensive Labour Force Survey (CLFS). We found that even after graduates from the expanded AU cohorts entered the labour market, thereby increasing the relative supply of university graduates (Exhibit 3), the relative wage of university graduates vis-à-vis polytechnic graduates – a comparator group chosen for technical reasons[3] – remained stable (Exhibit 4).

Exhibit 3: Relative supply of resident workers with university degrees to non-degree holders[4]
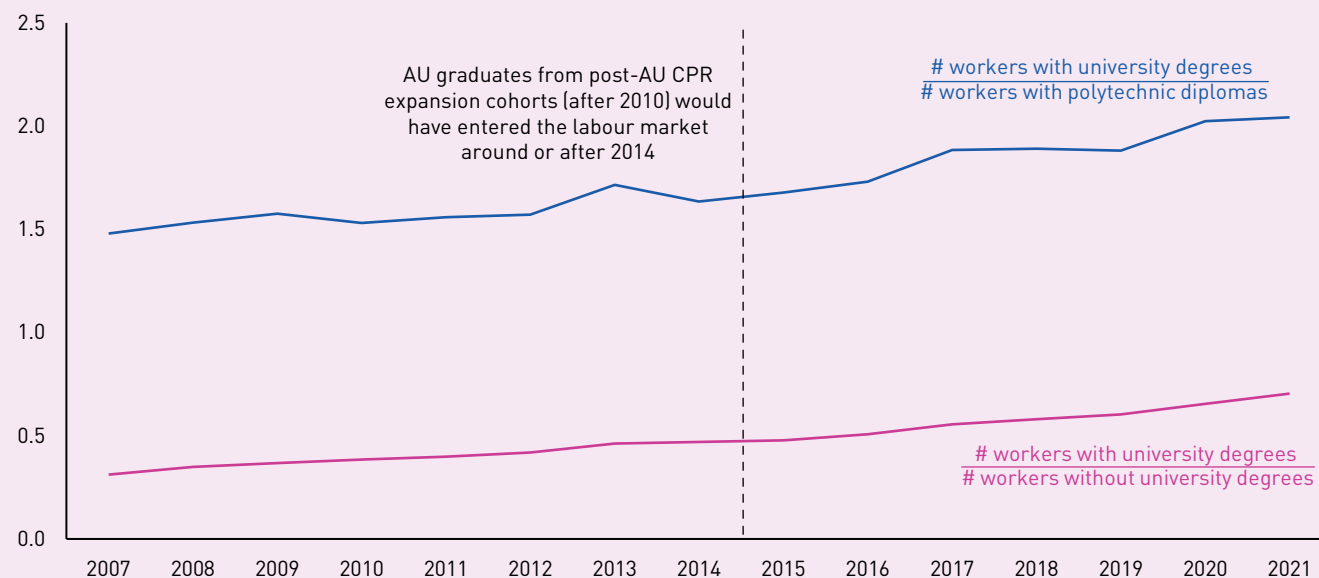
Source: Ministry of Manpower's (MOM) Comprehensive Labour Force Survey (CLFS)

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3   We used polytechnic graduates as the main comparison group for technical reasons. Specifically, polytechnic graduates were likely to be more similar to university graduates than secondary graduates for example, which would allow us to minimise the impact of compositional differences across workers (e.g., in terms of family background, ability, or motivation) on relative wage.

4   Resident workers with degrees include graduates from Private Educational Institutions and overseas universities. While we presented the supply in relative terms, data from the CLFS showed that the absolute supply of university graduates also rose over the same period, from 438,000 in 2007 to 945,000 in 2021.

Exhibit 4: Change in relative wage of university graduates vis-à-vis polytechnic graduates compared to 2014, for all resident workers and resident workers aged 25 – 29
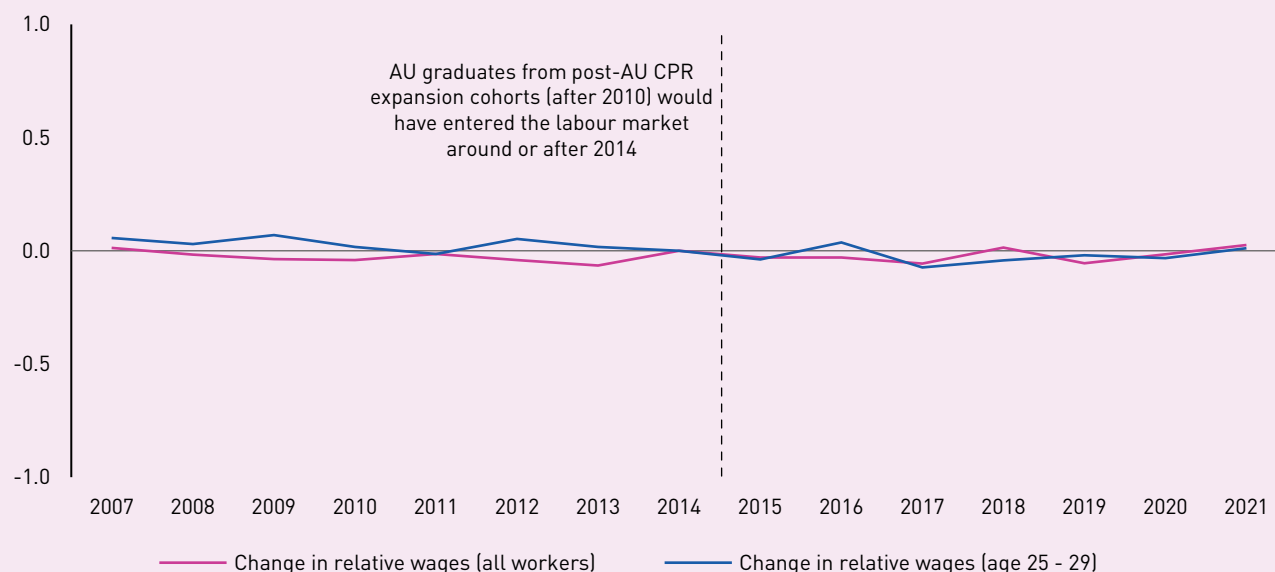
Source: MOM's CLFS

While these economy-wide statistics provide suggestive evidence that the labour market has adjusted to the AU CPR increases well, there is still the possibility that the relative wage changes presented are not reflective of the impact of the AU CPR increases if the AU CPR increases had also led to a change in the composition of university and polytechnic graduates, especially in terms of variables that could independently affect their wages such as ability, demographics or socioeconomic status.

To mitigate this issue, we next conducted regression analyses using individual-level data.

(i) Data and methodology for individual-level analysis

We carried out econometric analyses using individual-level data, which would allow us to account for potential confounders such as the demographic and socioeconomic characteristics of individuals.

Specifically, we used administrative data for the period of 2005 to 2021, and focused on residents (i.e., Singapore Citizens and Permanent Residents) in the 1986 to 1995 birth cohorts who graduated from university or polytechnic, and for whom we were able to observe their wage outcomes at ages 26, 27 and 28.

This data allowed us to estimate changes in the relative wage of university graduates for the post- vs pre-AU CPR expansion birth cohorts (where pre-AU CPR expansion birth cohorts refer to those born in 1989 or earlier, while the post-AU CPR expansion birth cohorts refer to those born in 1990 or after) via fixed-effects regressions that accounted for potential confounders, including demographic characteristics and socioeconomic status. Like the summary statistics presented earlier, the comparison group in our main regression was limited to polytechnic graduates as they were likely to be more similar to university graduates than those from other educational groups. Finally, our regression analysis differentiated between AU and non-AU university graduates.

Our main regression specification was:

$$y_{i,a} = \sum_g \alpha_g \cdot edu_{i,a,g} + \sum_c \alpha_c \cdot cohort_{i,c} + \sum_g \sum_{c \in [1986,1988]} \delta_{gc} \cdot (edu \times cohort)_{i,a,g,c}$$
$$+ \sum_g \beta_g \cdot (edu \times post - expansion\ indicator)_{i,a,g,c} + \gamma X_i + \varepsilon_{i,a}$$

where i,a,g,c indexed individuals, age, educational group, and birth cohort respectively, and

- $y_{i,a}$ was the log of monthly real wage[5];
- $edu_{i,a,g}$ were indicators for individuals with AU or non-AU degrees; the base/omitted category consisted of individuals with polytechnic diplomas (e.g., an AU indicator would take the value of 1 if an individual had an AU degree, and 0 otherwise);
- $cohort_{i,c}$ were birth cohort indicators (e.g., an indicator for the 1990 birth cohort would take the value of 1 for an individual from the 1990 birth cohort, and 0 otherwise); 1989 was the omitted cohort as it was the last birth cohort where the majority of individuals were not affected by the AU CPR increase;
- $post - expansion\ indicator$ was an indicator variable that took the value of 1 for the cohorts affected by the AU CPR increase (i.e., the 1990 – 1995 birth cohorts), and 0 otherwise;
- X_i were controls for sex, parental education, parental housing type, and parental income; and
- $\varepsilon_{i,a}$ was the error term

The coefficient of interest in this regression is β_g, which is an estimate of how the relative wage of university graduates (vis-à-vis polytechnic graduates) changed for the cohorts affected by the AU CPR increase, after accounting for differences in individual characteristics.[6]

In addition, we performed several robustness checks in line with the literature (e.g., Blundell et al., 2000) to remove or reduce the influence of other potential confounders. The two key checks we carried out were:

- <u>Incorporating national examination scores into the regression</u>. As national examination scores are observable proxies of students' ability/motivation which could have affected the wages of university and polytechnic graduates independently of the AU CPR increases, including the scores in the regression would help to better control for these potential confounders.

- <u>Restricting the sample to AU applicants</u>. This robustness check limited the comparison group of polytechnic graduates to those who had applied to, but did not enter, the AUs. As this is a group that was likely to be more similar to AU graduates in terms of unobservable confounders such as motivation, restricting the sample to this group could help to remove the effect of these confounders.

(ii) Impact on relative wage

Our regression results suggest that the **increase in the relative supply of university graduates arising from the AU CPR increases was broadly matched by a rise in relative demand**. Following the AU expansion (i.e., after the 1989 birth cohort), β_g for AU and non-AU graduates was close to zero and statistically insignificant for our main regression and robustness checks (Exhibit 5). This implies that the relative wage of university graduates (vis-à-vis polytechnic graduates) remained unchanged even after the AU CPR was raised.[7]

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5   Real wages were deflated using the Consumer Price Index, with 2019 as the base year.
6   More precisely, β_g is an estimate of how wages changed for birth cohorts affected by the AU CPR increase, relative to the 1989 birth cohort, the last cohort where most individuals were not affected by the AU CPR increase.
7   The stability observed in the relative wage of university graduates is consistent with Blundell et al. (2022), who found that university expansions in the UK did not change the relative wage of degree holders.

Exhibit 5: Change in relative wage of AU and non-AU graduates after AU CPR increases, ages 26 – 28[8]

Change in relative wage after AU expansion (percentage-points)	Age 26		Age 27		Age 28	
	Non-AU	AU	Non-AU	AU	Non-AU	AU
Main regression	NA[9]	-1.2	-0.5	-1.2	0.8	-0.4
Robustness: No controls		-1.1	-0.7	-1.1	0.6	-0.4
Robustness: Controls for PSLE score		-1.2	-0.5	-1.3	0.7	-0.2
Robustness: Restricting sample to AU applicants only		1.1	1.6	-0.1	0.9	-0.1

*** p<0.01, ** p<0.05, * p<0.1. Statistically insignificant coefficients are in grey
Source: Authors' estimates

(iii) Impact on employment rates

Beyond wages, the labour market could have also adjusted to the AU CPR increases along the employment margin. However, we did not find evidence of this as summary statistics suggest that the employment rates of AU and non-AU university graduates, as well as polytechnic diploma graduates, remained high and stable after the AU expansion (i.e., after the 1989 birth cohort) (Exhibit 6).[10]

Exhibit 6: Employment rate by educational group and birth cohort at age 27[11]

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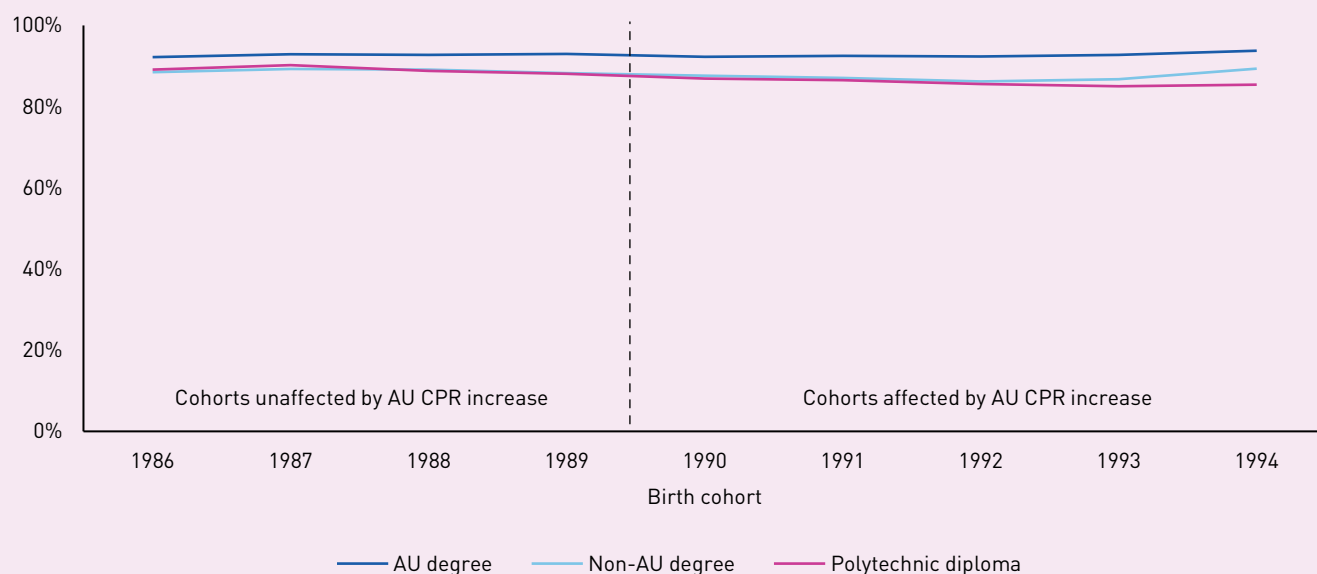
8   The results for the change in relative wage (i.e., β_g) at ages 26 – 28 are from three separate regressions that used wage at age 26, 27 and 28 as the outcome variable respectively.

9   The change in relative wage for non-AU degree graduates at age 26 is not reported as their wage had already diverged from that of polytechnic graduates in the birth cohorts unaffected by the AU expansion, which implies that any further changes in their relative wage at age 26 would likely not be attributable to the AU expansion. By contrast, the wages of AU graduates and non-AU graduates at other ages had not diverged from those of polytechnic graduates prior to the increase in the AU CPR.

10   Employment rate was computed as the number of individuals in formal employment divided by the number of individuals in a birth cohort (i.e., not restricted to economically active individuals only).

11   While the exhibit shows the employment rate of individuals at age 27, the trends are similar at ages 26 and 28.

POTENTIAL CHANNELS UNDERLYING STABILITY IN RELATIVE WAGE

(i) Data and methodology for analyses used to better understand demand channels

Our second set of econometric analyses focused on exploring the channels through which the relative demand for university graduates could have changed, by explicitly modelling relative demand changes as well as changes in the supply of workers in different age and educational groups.[12]

Specifically, we followed the literature (Katz & Murphy, 1992; Card & Lemeuix, 2001; Goldin & Katz, 2007; Blundell et al., 2022) and estimated the following theoretically-motivated relative demand equation (see Annex A for derivation) on a dataset of all resident workers aged 25 and above that was aggregated by educational groups, 5-year age bands and sectors:

$$\log \frac{w_{H,j,st}}{w_{M,j,st}} = b_{0,s} + b_{0,j} + f(t) + b_e \log \frac{L_{H,st}}{L_{M,st}} + b_a \left(\log \frac{L_{H,j,st}}{L_{M,j,st}} - \log \frac{L_{H,st}}{L_{M,st}}\right) + \epsilon_{e,j,s,t}$$

where:

- L represents total employment in the education x age band x sector cell;
- e, j, s, t index education group, 5-year age band, sector, and year, respectively;
- H, M, and L represent the high (degree[13]), mid (polytechnic), and low (post-secondary and below) education categories, respectively;
- $f(t)$ is a function of time (e.g., linear or quadratic time trends); and
- b_e and b_a are the inverse of the elasticities of substitution between education groups (i.e., university degree and polytechnic graduates) and age groups (i.e., 5-year age bands), respectively.

This analysis allowed us to test whether the increase in relative demand for university graduates suggested by our findings in the earlier section was more likely to have arisen from exogenous demand changes or endogenous technological choice. The basic idea is as follows:

- If the relative demand for university graduates had risen in tandem with relative supply, and we did not explicitly model the demand shocks, there should be little or no correlation between the increase in the relative supply of university graduates and their relative wage (i.e., $b_e = 0$).

- If the demand increases were due solely to exogenous demand shocks, econometrically removing the effects of these shocks would restore the negative correlation between the relative supply of university graduates and their relative wage (i.e., $b_e < 0$). To net out exogenous demand, we added a secular time trend $f(t)$ in the regression specification (i.e., exogenous demand is assumed to be modelled by the time trend variable).

- By contrast, if the demand increases were due solely to endogenous demand shocks, adding the secular time trend $f(t)$ to the regression would not have any effect. There would thus still be little or no correlation between the increase in the relative supply of university graduates and their relative wage (i.e., $b_e = 0$).

We excluded the third demand channel highlighted earlier (i.e., endogenous innovation) from consideration as our assessment was that it was unlikely to have been a key driver of relative demand shifts over the period of our study. Specifically, increases in relative demand for university graduates arising from the invention of skill-intensive technologies typically occur with a lag, which is inconsistent with our observation of a stable relative wage shortly after the increase in the relative supply of university graduates occurred (see Exhibits 4 and 5).[14]

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12 *The drawback of this approach is that we were not able to adjust for confounders as easily given that the data was aggregated and the variables used to control for confounders in the earlier analysis were not available for all observations in the full dataset.*

13 *Degree holders include both AU and non-AU university degree holders as data on whether an individual graduated from an AU was not available for the full dataset.*

14 *Beyond the three channels discussed, which would serve to raise wages if university education led to actual increases in human capital on the supply side, the literature also suggests the possibility of a separate supply channel – i.e., signalling – which could similarly raise the wages of university graduates. Under the signalling channel, employers use degree attainment as a signal of innate ability and are thus willing to pay more to hire university graduates. However, our assessment is that signalling was unlikely to have been a driver of changes in the relative wage of university graduates in our context. This is because if signalling had been a key factor, AU expansions would have weakened the signalling value of a degree over time and thus reduced the relative wage of university graduates. However, this was not what we observed in our study, i.e., the relative wage of university graduates remained stable over time even after the AU expansions.*

(ii) Results

Using the above approach, we found evidence that the increase in relative demand for university graduates after the AU expansions was likely to be primarily due to exogenous demand increases. At the same time, there was some suggestive evidence that endogenous demand increases due to technological choice could have contributed to some extent too (Exhibit 7). (See Annex B for the detailed results.)

First, exogenous demand increases were likely to be a key driver of the increase in relative demand for university graduates as: (i) the correlation between the time trend and relative wage of university graduates (i.e., $f(t)$) was positive and statistically significant; and (ii) the addition of the time trend (which accounted for the effect of exogenous demand increases) restored part of the expected negative correlation between the relative supply of university graduates and their relative wage (i.e., $b_e < 0$), although the b_e term remained statistically insignificant. An analysis of job vacancies by sector before and after the AU CPR was increased suggests that the rise in labour demand for university graduates could have been driven by skill-intensive sectors such as the Finance & Insurance and Information & Communications sectors (Annex C).

Second, exogenous demand increases were unlikely to be the only driver of the increase in relative demand for university graduates as the negative correlation between the relative supply of university graduates and their relative wage remained relatively small (and statistically insignificant) even after exogenous demand increases were accounted for in our regression using the time trend. Beyond these regression results, the stability of the relative wage of university graduates in Exhibits 4 and 5 provides further evidence that exogenous demand increases were unlikely to be the only driver of the relative demand shifts, as it is unlikely that exogenous demand could have increased to the extent needed to match the rise in the relative supply of university graduates year after year, for more than a decade. Taken together, these observations suggest that the remaining channel under consideration – i.e., endogenous technological choice – could have also contributed to the rise in relative demand for university graduates over the period of our study.

Exhibit 7: Summary of relative demand regression results

Correlation between variable and relative wage of university graduates for:	Predicted regression result for each channel after adding time trends to net out exogenous demand increases		Actual regression result
	If only exogenous demand	**If only endogenous technological choice**	
Relative supply of university graduates (i.e., b_e)	• Negative and statistically significant	• Close to 0 or positive	• Negative but statistically insignificant • Smaller than benchmarks from the literature
Time trend (i.e., $f(t)$)	• Positive and statistically significant	• Close to 0	• Positive and statistically significant

CONCLUSION

Our study suggests that the increase in the relative supply of university graduates arising from the 2011 – 2016 AU CPR increases was matched by a rise in the relative demand for these graduates, as there was no evidence of a fall in the relative wage of university graduates. This was likely to be largely due to a concurrent rise in exogenous demand for university graduates from sectors such as Finance & Insurance and Information & Communications. It could potentially also be due to endogenous technological choice (i.e., the higher supply of university graduates could have led firms to shift towards existing skill-intensive technologies), albeit to a lesser extent.

A key caveat to our study is that our focus was only on the private returns to AU education. There are likely to be broader societal returns to AU education, such as improved economy-wide productivity from increased innovation or agglomeration effects, that were not captured in our study. Notwithstanding this caveat, our overall findings are encouraging and suggest that our economic agencies have been successful in anchoring firms and skilled jobs in Singapore, and that our AUs have been able to nurture a skilled workforce that is able to compete successfully for and perform well in these jobs.

In March 2023, in close consultation with MTI, MOM and other economic agencies, MOE announced plans to increase the Lifetime AU CPR for publicly-funded university degrees to 60 per cent by 2025. This takes into account the demand for degree-level manpower across the economy in the medium term, arising from our industry transformation efforts. The increase will be weighted towards enabling adult learners to access university education, and spread over time so that the curricula can adjust in response to industry demand. MOE will continue to work with agencies to support the AUs in equipping students with the necessary skills to take on good jobs in the economy, and closely monitor the labour market outcomes of all students across the various education pathways.

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ANNEX A: DERIVATION OF RELATIVE DEMAND REGRESSIONS

Similar to the literature (e.g., Card & Lemeuix, 2001; Goldin & Katz, 2007), our relative demand equation was derived based on an assumption of a Constant Elasticity of Substitution (CES) production function with two nests:

$$y_{st} = (\alpha_{H,t} L_{H,st}^{\rho} + \alpha_{M,t} L_{M,st}^{\rho} + \alpha_{L,t} L_{L,st}^{\rho})^{\frac{1}{\rho}} \quad \& \quad L_{e,st} = (\textstyle\sum_j \beta_j L_{e,j,st}^{\eta})^{\frac{1}{\eta}}$$

where:

- y and L represent output and labour, respectively;
- e, j, s, t index education group, 5-year age band, sector, and year, respectively;
- H, M, and L represent the high (degree), mid (polytechnic), and low (post-secondary and below) education categories respectively;
- α and β are the skill-group-specific factors augmenting technological or productivity factors for each nest and group; and
- $\rho = 1 - \frac{1}{\sigma_E}$ and $\eta = 1 - \frac{1}{\sigma_A}$, where σ_E and σ_A represent the elasticities of substitution between skill groups and age groups, respectively. An elasticity of between 0 and 1 suggests that the groups are gross complements, while an elasticity of more than 1 suggests that the groups are substitutes.

Taking the first order condition and rearranging terms gave us the following relative demand equation for high-skilled relative to low-skilled workers, where w represents wage, ϵ is the error term, and the other terms are the same as before:

$$\log \frac{w_{H,j,st}}{w_{M,j,st}} = \underbrace{\log \frac{\alpha_{H,t}}{\alpha_{M,t}}}_{\text{Relative exogenous demand}} + \beta_j + \delta_S - \underbrace{\frac{1}{\sigma_E} \log \frac{L_{H,st}}{L_{M,st}} - \frac{1}{\sigma_A} \left(\log \frac{L_{H,j,st}}{L_{M,j,st}} - \log \frac{L_{H,st}}{L_{M,st}} \right)}_{\text{Relative supply that accounts for substitution between ages}} + \epsilon_{e,j,st}$$

Assuming that relative exogenous demand is a function of time (i.e., $\log \frac{\alpha_{H,t}}{\alpha_{M,t}} = f(t)$) then gave the following estimable demand equation in the main text:

$$\log \frac{w_{H,j,st}}{w_{M,j,st}} = b_{0,s} + b_{0,j} + f(t) + b_e \log \frac{L_{H,st}}{L_{M,st}} + b_a \left(\log \frac{L_{H,j,st}}{L_{M,j,st}} - \log \frac{L_{H,st}}{L_{M,st}} \right) + \epsilon_{e,j,st}$$

where b_e and b_a are the inverse of the elasticities of substitution between educational groups (i.e., university degree and polytechnic graduates) and age groups (i.e., 5-year age bands), respectively.

ANNEX B: DETAILED RESULTS OF RELATIVE DEMAND REGRESSIONS

Across the regressions, the inverse of the elasticities of substitution between educational groups (b_e) became more negative (but still statistically insignificant) upon the addition of the time trend. The positive and statistically significant coefficient for the time trend implied that there was an exogenous, secular rise in relative skilled labour demand over time.

However, b_e remained statistically insignificant and less negative than typical estimates in the literature even after adding the time trend, suggesting the presence of some omitted variable bias. While this omitted variable bias could either be due to model misspecification or economy-wide relative demand shifts that we did not account for, we assessed that the former was less likely as the estimates of b_a were in line with the literature.[15]

As such, endogenous technological choice, the key remaining channel in the literature which we were unable to model explicitly, was a potential candidate for the source of the additional relative demand shift that had not been accounted for.

Exhibit B1: Results of relative demand regressions with different time trend assumptions

Coefficient	(1) No time trend	(2) Linear time trend	(3) Quadratic time trend
b_e	-0.007	-0.074	-0.071
b_a	-0.125***	-0.123***	-0.123***
Year		0.002**	0.462
Year^2			-0.0001
Sector FE	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Observations	3,753	3,753	3,753
R-squared	0.560	0.560	0.560

*** p<0.01, ** p<0.05, * p<0.1. Statistically insignificant coefficients are in grey.
Source: Authors' estimates

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15   A typical range for b_a is -0.2 to -0.1, while that for b_e is around -0.7 to -0.5 (e.g., Katz & Murphy, 1992; Card & Raphael, 2013).

ANNEX C: COMPARISONS OF JOB VACANCIES BY SECTOR

Analysing the change in average job vacancies by sector for the post-AU expansion period of 2017-2019, as compared to the pre-AU expansion period of 2010-2016, we found that the Finance & Insurance and Information & Communications sectors experienced the largest changes in average job vacancies of 1,800 and 1,700 respectively (Exhibit C1). This suggests that the rise in relative labour demand for university graduates could have arisen partly due to demand from these sectors.

Exhibit C1: Change in average job vacancies by sector (calendar year 2010-2016 vs 2017-2019)

Sector	Change in average job vacancies (thousands)
Manufacturing	-0.5
Construction	-0.8
Wholesale Trade	0.0
Retail Trade	-0.5
Transportation & Storage	-0.1
Accommodation	0.4
Food & Beverage Services	-0.3
Information & Communications	1.7
Finance & Insurance	1.8
Real Estate	-0.7
Professional Services	0.6
Administrative & Support Services	0.0
Other Services Industries	-1.5