Digitalisation and the labour force gender participation gap in the Indo-Pacific[1]

Abstract

Since 2000 the gap between female and male workforce participation in the Indo-Pacific has narrowed, while indicators of digital connectivity and internet use have grown rapidly. We find a robust and statistically significant correlation between Internet use and female workforce participation controlling for country fixed effects, a time trend, and numerous other controls. The most conservative estimate suggests that, on average, growth in Internet use has been associated with around two-thirds of the increase in female participation in the Indo-Pacific since the year 2000. Instrumental variables estimation finds support for a causal relationship between Internet use and female participation, and indirectly points to the importance of the free flow of information online for female participation in the region. We also find an insignificant relationship between trade and female participation. Despite finding a positive association between internet use and female participation, a number of barriers exist that are preventing women from fully sharing in the benefits of the digital economy. Based on preliminary findings from the G20 Taskforce on Digitalisation, we consider a range of measures that policymakers in the Indo-Pacific can pursue to address these barriers.

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The digital economy is expanding rapidly in the Indo-Pacific, helping boost growth and expand economic opportunities at a time of otherwise disappointing global productivity growth. On the one hand digitisation has created new possibilities for the economic empowerment of women through increasing services employment, access to flexible work arrangements and home based production-activities that have traditionally helped support higher levels of female labour force participation and economic empowerment. Despite this potential, concerns have been expressed that the benefits of digitisation are not being shared equally by women; that women face higher barriers to participation in the digital economy compared to men; and that digitisation may see a reduction in job quality for women.

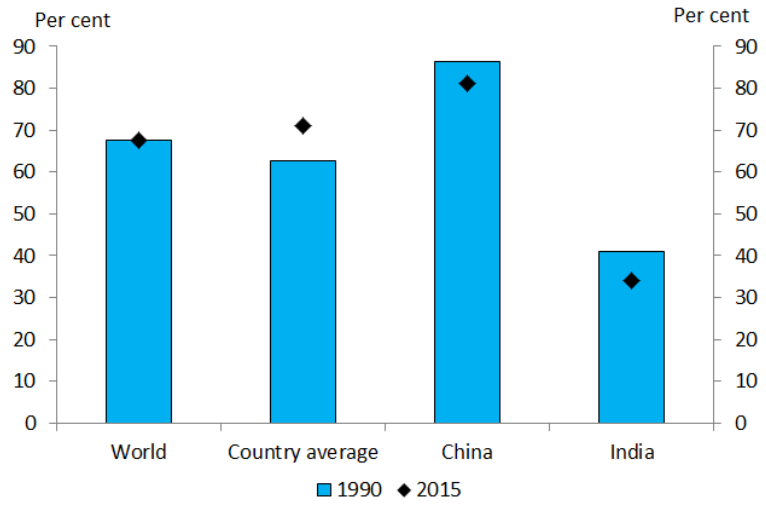
A legacy of Australia's 2014 G20 Presidency was the Brisbane commitment to reduce the gap between male and female labour force participation rates by 25 per cent by 2025. In the G20 the Australian Government is advocating for G20 economies to take steps across a range of public policy areas to help bridge the digital gender divide and ensure women prosper in the new world of work. As a result of this advocacy, at the first ever G20 Digital Economy Ministers' Meeting in April 2017 in Dusseldorf, G20 Digital Economy Ministers' agreed to support the equitable participation of women in the digital economy. As a first step in the G20s actions to help increase the economic empowerment of women in the digital economy, G20 members exchanged learnings from domestic policy actions at the final G20 Digital Economy Taskforce Meeting of the German Presidency in October 2017. The OECD is currently conducting a survey of international best practices to report to G20 Leaders in late 2018.

This paper seeks to address two questions. First, what is the relationship between female workforce participation and the digital economy in the Indo-Pacific since the turn of the century focusing on internet usage as an indicator of digital activity? Second, based on early insights gained from the work of the G20 Taskforce on Digitalisation on bridging the digital gender divide, what policies can countries in the Indo-Pacific prioritise to ensure that women can fully share in all the benefits the digital economy has to offer? For the purposes of our analysis the Indo-Pacific countries include the countries of Asia, Oceania and the Pacific coast of the Americas.

Women's workforce participation and digitisation in the Indo-Pacific: What does the data show?

The global female-male participation ratio has remained steady for nearly three decades at just under 68 per cent (Chart 1). However, the average participation ratio across all countries has actually increased by 8.4 percentage points over the same period. The main reason for this divergence is that the two most populace nations, India and China, have both seen a decrease in the participation ratio over this period. This reflects the fact that economic development is the primary driver of women's labour force participation, with female participation following a U-shaped trajectory as countries move from low to high income status (Goldin, 1995).

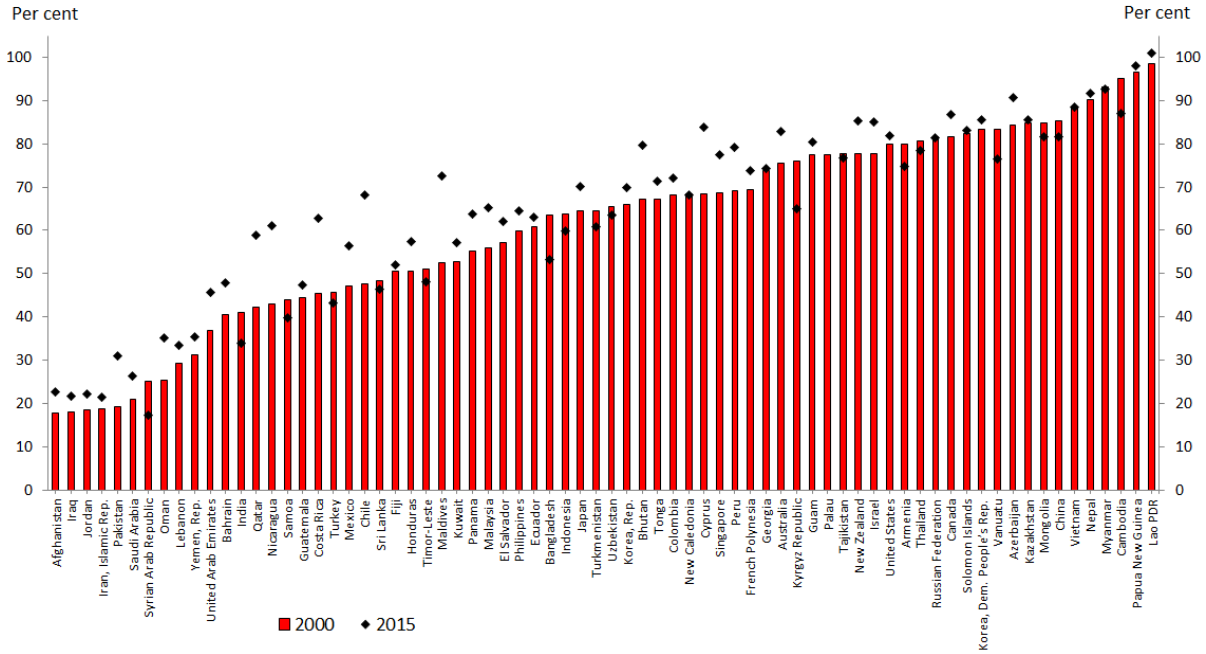
Chart 1: Female-male participation ratio, per cent



Source: World Bank

Since the year 2000 most countries in the Indo-Pacific have experienced an improvement in female labour force participation relative to men (Chart 2). However, it remains the case that many countries in the Indo-Pacific region have very low levels of female participation.

Chart 2: Female-male participation ratio by Indo-Pacific country, 2000 to 2015

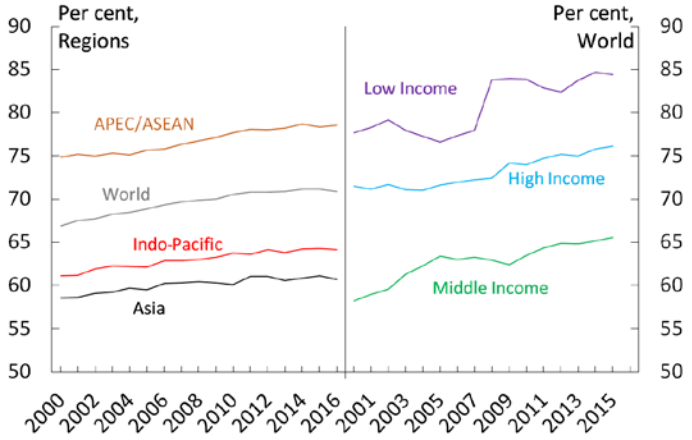


Source: World Bank

Since 2000 the average gap between female and male labour force participation has also been declining in the Indo-Pacific region (Chart 3). However, it appears that progress in closing the gap has stalled somewhat over the past five years, a trend that also seems to be globally apparent. In panel 1 of Chart 3 it is interesting to note the level differences between different country groupings. The APEC/ASEAN countries have much higher participation ratios relative to the Asian countries which include the Middle East and the sub-continent, and the Indo-Pacific countries which include all Asian countries, as well as the Pacific island nations and the west coast of the Americas. The second panel of Chart 3 clearly reveals the U-shaped pattern between growth and development. Interestingly,

female-male participation ratios have been growing within all income categories and regions over time. The global and regional plateauing of the participation ratio evident in panel 1 of Chart 3 appears to be predominantly driven by a plateauing of the participation ratio in low income countries.

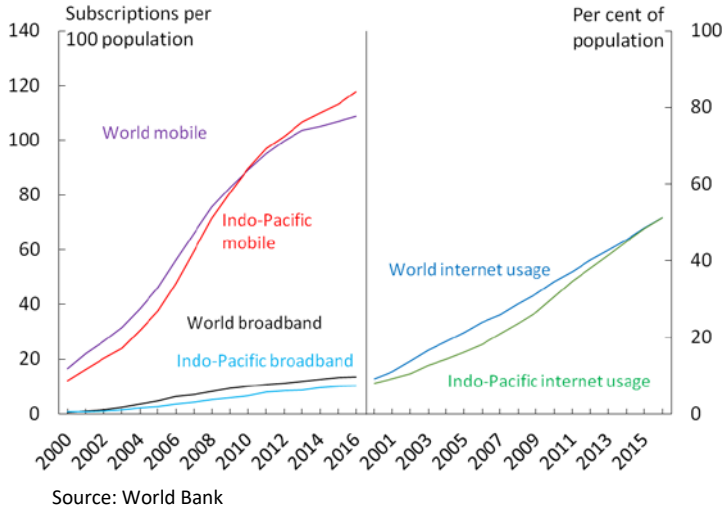
Chart 3: Female-male participation ratio by region and income, per cent



Source: World Bank

Chart 4 demonstrates that indicators of digital activity have also increased significantly since the turn of the century, both globally and in the Indo-Pacific. In recent years growth in mobile penetration in the Indo-Pacific has actually outpaced that at the global level, while broadband penetration rates have grown at a rate below that of the worldwide average. In recent years the average level of internet usage in the Indo-Pacific use has caught up with the global average, which was most likely driven by the rapid growth in mobile penetration.

Chart 4: ICT connectivity by region



Source: World Bank

Model

To get a more formal sense of the impact of digitisation on female workforce participation in the Indo-Pacific we estimate a range of panel regression models controlling for time and country fixed effects, and a range of other correlates with female participation identified in the literature. Our basic modelling specification is as follows:

$$FPR_{it} = \alpha + \beta_0 \cdot INTERNET_{it} + \beta_1 \cdot Z_{it} + \gamma_i + \delta_t + \varepsilon_{it} \qquad (1)$$

Where FPR_{it} is the female labour force participation rate for country *i* in period *t*, and $INTERNET_{it}$ is internet use as a proportion of the population which acts as our indicator of digital activity. Z_{it} is a vector of additional control variables including GDP per capita; fertility rates; female life expectancy; education spending as a proportion of total government spending; the trade to GDP ratio; and the agricultural and services shares of the economy. The model specification also includes time and country dummy variables (δ_t and γ_i) to control for time and country specific fixed effects. The use of country dummies to model country specific fixed effects assumes that sources of time invariant heterogeneity between countries related to factors such as cultural norms, religious attitudes or legal systems may be correlated with explanatory variables used in the regression. The model was estimated using the Prais-Winsten technique with panel corrected standard errors (PCSEs). PCSEs are robust to contemporaneous correlation and heteroscedasticity between panels, and first order serial autocorrelation within panels.

GDP per capita is included in estimation to control for the influence of the general level of economic development between countries. Fertility rates control for the fact that birth control and declining fertility levels are likely to be associated with higher levels of female participation. Female life expectancy is used as an indicator of general health characteristics, and we expect it to be negatively related to female participation. This is because better population health should be associated with higher levels of productivity and economic development. This in turn is expected to support longer periods outside of the labour force for family purposes and in retirement relative to low income, subsistence economies. We also expect higher levels of government spending on education relative to total government spending to be associated with higher levels of female workforce participation.

ADB (2015) suggest that trade can make domestic labour markets more competitive, increasing the costs of employer discrimination against female employees. Further Cavalcanti and Tavares (2008) suggest that relative declines in the price of labour saving technologies driven by trade cam also help increase female workforce participation. These considerations suggest that a country's trade share relative to GDP should be positively related to female participation. We also include the agriculture and services shares of GDP as controls following suggestions that countries with a higher agricultural share of production or rural population experience higher female participation. A higher services share is also commonly associated with higher levels of female participation because services industries can be viewed as more culturally appropriate for women in some societies, and are typically more conducive to part-time and flexible work arrangements that tend to enable higher levels of participation for people with caring responsibilities who are disproportionately female.

Results

Table 1 reports regression results with all model specifications revealing a statistically significant and positive relationship between Internet use and female participation that is relatively stable between model specifications. Based on the range of parameter estimates reported in Table 1, the average 40.4 percentage point increase in Internet use in the Indo-Pacific between 2000 and 2015 is associated with between a 1.2 and 2.4 percentage point increase in the female participation rate over the corresponding period. That is equivalent to between approximately two-thirds and one and one-third of the increase in the female participation rate between 2000 and 2015. While this is highly significant, it is important to note that there have been divergent influences on female participation over the period. Increasing female life expectancy and a declining agricultural share of production have reduced female participation on average in the Indo-Pacific during the period. For example, the increase in female life expectancy alone over this period is associated with between a 2.6 to 3.4 percentage point decline in average levels of female participation in the Indo-Pacific based on the range of parameter estimates reported. On the other hand, economic development as reflected by

increases in GDP per capita; and increasing education spending as a proportion of total government spending have also contributed to higher levels of female workforce participation on average in the region since 2000. Declining fertility rates on average may also have contributed to higher participation, however parameter estimates are not statistically significant in all model specifications.

Table 1: Determinants of Female Labour Force Participation in the Indo-Pacific (PCSE)

Dependent variable: Female participation rate, 2000-2016								
Equation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	29.47*	39.35***	29.28*	58.6***	73.97***	59.18***	51.56***	49.93***
	(2.11)	(5.72)	(2.14)	(5.82)	(9.73)	(6.48)	(4.90)	(4.69)
Internet use	0.05***	0.06***	0.05***	0.03***	0.04***	0.04***	0.04***	0.03**
	(5.91)	(5.96)	(5.69)	(4.39)	(5.93)	(4.64)	(3.35)	(3.13)
GDP per capita		0.00***	0.00***	0.00**	0.00***	0.00***	0.00***	0.00***
		(4.80)	(4.93)	(3.16)	(4.61)	(9.37)	(8.82)	(7.82)
Trade share			0.00	0.01	0.00	0.01	0.01	0.01
			(1.02)	(1.62)	(1.39)	(1.66)	(1.61)	(1.47)
Female life exp.				-0.73***	-0.82***	-0.66***	-0.64***	-0.62***
				(-4.88)	(-6.54)	(-4.46)	(-3.83)	(-3.59)
Fertility rate					-1.54***	-0.69*	-0.46	-0.18
					(-5.83)	(-2.07)	(-1.06)	(-0.37)
Educ. Exp.						0.09*	0.10*	0.10**
						(2.38)	(2.53)	(2.59)
Ag. share							0.18***	0.17***
							(4.03)	(3.83)
Services share								-0.03
								(-1.29)
Country dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
N	1053	995	965	919	919	549	504	504
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Wald test (p>χ^2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: * p<0.05; ** p<0.01; *** p<0.001. z statistics are in brackets. Wald tests are on the null of all parameters being equal to zero.

Trade's share relative to GDP is economically and statistically insignificant in all model specifications (Table 1). This is perhaps unsurprising as on average trade grew strongly in the region before the Global Financial Crisis, and has been receding since. While at the same time female participation has grown steadily over the entire period. Overall, trade does not appear to have had a negative impact on female participation in the region between 2000 and 2016, a period that has seen the rapid expansion of global value chains. The results also suggest that technological change has had a much more significant influence on female participation in the region since 2000 relative to trade.

We find stronger empirical support for a linear relationship between GDP per capita and the female participation rate in the Indo-Pacific, rather than the U-shaped relationship predicted in the literature

(see Goldin (1995) for instance). In results not reported we found evidence in favour of the quadratic relationship in models estimated using global data, including for high, middle and low income sub-samples.

As discussed, we find a negative and statistically significant relationship between fertility rates and female participation in some, but not all, model specifications. This is in contrast to models estimated with the female-male participation ratio as the dependent variable (not reported), where the fertility rate was statistically significantly negatively related to the female-male participation ratio in all specifications. Parameter estimates for female life expectancy were negative, as expected, and statistically significant in all model specifications. We also find a positive and statistically significant relationship between education's share of total government spending, and female participation as expected.

A positive and statistically significant relationship was found between the agricultural share of the economy and female participation in the Indo-Pacific between 2000 and 2016. This is in contrast to models estimated with the female-male participation ratio as dependent variable (not reported), where the agricultural share is not significant in all models. This suggests that a larger agricultural share of production is an indicator of higher levels of female participation in the region; however, on average women are not disproportionately represented in the agricultural sector relative to men. On average we found no relationship between the services share of GDP and female participation in contrast to models estimated using global data, and for high income countries in particular (not reported).

Causality

So why might higher levels of internet usage be positively associated with female workforce participation? Since the turn of the century the Internet has enabled an increase in the pace of knowledge and technology transfer across borders, helping to drive increases in productivity. For example, the World Bank (2009) estimated that a 10 percentage point increase in internet use is associated with a 0.77 percentage point increase in GDP growth in high income countries and a 1.12 percentage point increase in growth in low and middle-income countries. Between 2000 and 2015 internet use increased by just over 40 percentage points on average in the Indo-Pacific. There is also some evidence suggesting that the productivity benefits of digitalisation and the Internet may be under-measured in national accounts. For example, Coyle and Mitra-Kahn (2017) find that mismeasurement of GDP growth related to fixed and mobile broadband data use could add up to 1.5 percentage points per annum to UK real GDP growth between 2010 and 2015. Increased output and productivity related to the Internet and digitisation, combined with changing social attitudes towards women in the workforce, should translate into increased demand for female workers, and higher female workforce participation.

The digital economy also supports greater services employment, and part-time and flexible work arrangements, which have traditionally benefitted female workforce participation. The Internet and digital technologies can also support teleworking arrangements and home production activities which may help men and women better balance work and family responsibilities. Digital technologies also facilitate more efficient labour market search which would be anticipated to increase female participation.

However, a statistically significant association between internet usage and increasing female labour force participation does not imply that one causes the other. Some of the increase in Internet use in the region is no doubt driven by increased levels of female workforce participation (demand directed technical change). However, it should be noted that it is practically unlikely that much of the 40.4

percentage point average increase in Internet usage between 2000 and 2015 could be attributed to a 1.8 percentage point average increase in female participation over the same period. The great majority of the increase in Internet use is likely to have been driven by rapid innovation in ICT products, and the related decline in the relative price of ICT products and services over the period.

To formally assess the causal connection running from Internet use to female workforce participation, we need to find instrumental variables that are strongly related to increases in internet use, and unlikely to directly affect female participation rates. We anticipate that variables representing Internet freedom will be strongly positively correlated with Internet use, and not correlated with female participation. Further, we anticipate that variables reflecting state control over traditional media sources, such as access to foreign newspapers and television channels, should be negatively correlated with internet use, and not correlated with female participation. This is on the basis that higher levels of state control over traditional media sources is likely to encourage citizens to seek information through other means, such as the Internet, which may be inherently more difficult for governments to control. State control of the Internet in particular is also of interest from a policy perspective because it provides an insight into how important the free flow of information online is to internet usage, and broader economic outcomes such as female workforce participation.

Helpfully, the CATO Human Freedom Index includes subindexes representing "state control over Internet access", "laws and regulations that influence media content", "political pressures and controls on the media", and "access to foreign information" in the form of foreign newspapers and television channels. A score of 10 under each sub-index represents the highest degree of Internet or media freedom, and zero the absence of freedom. Unfortunately this information is only available for 2008 and the 2010-2014 period, with small sample sizes exacerbating the loss of estimation efficiency of two-stage least squares estimation.

In experimenting with different first stage regressions, state control over Internet access, combined with either laws influencing media content or political pressure on the media outlets appeared the most promising instruments. That is they had the most statistically significant relationships with internet usage. However, somewhat paradoxically, in second stage regressions state control of the Internet and access to foreign information were the best performing instrumental variables. First stage regressions regressing internet usage on state control of the Internet, access to foreign information and all the other right hand side variables used in estimation are reported in Table 2 of the Appendix. Wald tests reject the null hypothesis that coefficients for the instrumental variables are equal to zero in the first stage regressions for seven equations at the 5 per cent significance level, and one equation at the 10 per cent level (Appendix, Table 3).

Tables 2 reports second stage regressions for the female participation rate where we instrument for internet use using state control of the Internet and access to foreign information as instruments. With the exception of equation 2, under most model specifications instrumental variables estimation actually suggests a stronger causal relationship between internet usage and female participation than under standard estimation. However, given the different sample periods, it may just be that internet use has become a more important enabler of female workforce participation in more recent years. Less efficient parameter estimation under instrumental variables estimation is to be expected, especially given the relatively small sample sizes. Sargan-Hansen overidentification tests strongly support the null of instrument validity in each model specification. The sign has reversed for the trade share parameters due to the fact that trades share declined on average for Indo-Pacific economies between 2008 and 2014, whereas trades share was strongly increasing in the pre-GFC period.

Table 2: Determinants of Female Labour Force Participation in the Indo-Pacific - Instrumental variables (PCSE)

Dependent variable: Female participation rate (2008, 2010-2014)								
Eq.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	50.88***	38.10***	53.94***	133.81***	120.93***	426.74***	421.98***	420.31***
	(47.10)	(9.92)	(14.54)	(6.87)	(6.86)	(7.96)	(8.01)	(7.44)
Internet use	0.16**	0.15***	0.10	0.15*	0.15*	0.24**	0.18**	0.21**
	(2.94)	(1.05)	(1.66)	(2.25)	(2.41)	(2.96)	(2.59)	(2.53)
GDP per capita		0.00***	0.00*	0.00	0.00	0.00	0.00	0.00
		(3.72)	(1.99)	(1.49)	(1.76)	(0.44)	(0.72)	(0.09)
Trade share			-0.03*	-0.04**	-0.04**	-0.07**	-0.04*	-0.05
			(-1.97)	(-2.90)	(-3.11)	(-2.66)	(-2.12)	(-1.94)
Female life exp.				-0.78***	-0.98***	-4.45***	-4.45***	-4.41***
				(-3.48)	(-4.10)	(-6.80)	(-6.89)	(-6.59)
Fertility rate					-0.35	-10.98***	-9.10**	-9.37**
					(-0.28)	(-3.20)	(-2.78)	(-2.76)
Educ. Exp.						0.20*	0.13	0.15
						(2.23)	(1.52)	(1.58)
Ag. share							0.09	0.09
							(0.96)	(1.04)
Services share								-0.02
								(-0.30)
Country dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.02
N	300	300	294	294	294	193	193	186
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Wald test (p>χ^2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overid. test (p>χ^2)	0.32	0.30	0.33	0.82	0.73	0.15	0.18	0.25

Notes: * p<0.05; ** p<0.01; *** p<0.001. z statistics are in brackets. Wald tests are on the null of all parameters being equal to zero. Overidentification test is the Sargan-Hansen test with null of valid instrumental variables.

In summary, our results suggest a positive and significant causal relationship between internet use and female labour force participation in the Indo-Pacific region, at least since 2008. The evidence in favour of a positive effect of internet use on female participation on average across countries is robust to the introduction of a range of controls, including country and time dummies, and a range of factors associated with female participation identified in the literature. Indirectly, we find evidence that freedom of the Internet from state interference and the free flow of information online are also associated with higher levels of female labour force participation in the Indo-Pacific.

A conceptual framework for policies to bridge the digital gender divide

While we find a statistically significant and positive relationship between Internet use and female participation for countries in the Indo-Pacific region, there are still many barriers that can prevent

women from fully sharing in the benefits of the digital economy. Policy actions to address these barriers can be roughly divided into four separate categories: Access, skills and entrepreneurship, norms and data. Access relates to ensuring universal access to digital connectivity as an essential underpinning of active participation in the digital economy. Once access is enabled digital skills are critical to allow for the effective use of digital technologies. Norms refer to the stereotypical views about the suitability of women for digital careers, and other societal barriers often embedded in regulations and institutions that can hold women back from more actively participating in the digital economy. A final barrier to women's participation in the digital economy is the lack of gender-specific ICT data in national statistics which can make it difficult for policy makers to apply a gender lens in evidence-based policy development and evaluation. A better evidence base is urgently required to help inform the development and evaluation of policy actions to bridge the digital gender divide.

What can and should governments' be doing to bridge the digital gender divide?

The first insight gleaned from the G20 Taskforce on Digitalization's ongoing focus on bridging the digital gender divide is that national broadband, digital and entrepreneurship policies and strategies should incorporate a gender perspective that addresses women's needs, circumstances, capabilities and preferences.[i] Governments should also consider incorporating gender equality targets for Internet and broadband access and use in these strategies as and where appropriate. Governments should mainstream the application of formal gender impact analysis to all new policy proposals in these areas, and mainstream gender equality and ICT linkages within sectoral strategies and innovation systems.

It goes without saying that digital development and innovation is proceeding at a more rapid pace in the private sector than the public sector. Businesses, governments and civil society all share a common interest in fostering digital inclusion, and this presents a range of opportunities for government to partner with the business and not-for-profit sector. Therefore, it may be valuable for policy makers in the Indo-Pacific region to consider leveraging existing private sector and civil society initiatives as a means to increase universal, equitable, safe, and affordable access to the Internet and other digital technologies, as well as increase women and girls' engagement in STEM, where these programs have proven to be effective.

For example, the GSMA's *Connected Women Commitment Initiative* aims to reduce the mobile gender gap by facilitating greater access to new technologies, and building the necessary skills to effectively use these technologies among consumers (GSMA, 2017). Microsoft offer the *Digigirlz* program and Careers Days through Australian Business and Community (ABCN) Programs to expose diverse high school students to the high-tech world. Microsoft has also founded the *HerTechPath* program to inspire girls to consider a career in technology.

Access

Our empirical analysis provides some evidence of an economically significant and positive association between internet usage and female participation in the Indo-Pacific region, reinforcing the link between access to fast and reliable connectivity and participation in the digital economy. However, globally around 1.7 billion women in low and middle-income countries do not own a mobile phone (GSMA, 2015), nearly 60 per cent of the world's population have no access to the Internet, and there are 250 million fewer women online than men (ITU, 2016).

The maintenance of open and competitive markets for the provision of communications infrastructure should be the primary policy approach to providing affordable access to connectivity. Where there are market failures that result in a lack of access to connectivity in particular regions or communities, there may be a role for governments to step in and directly fund or deliver infrastructure. As an

intermediate option, governments may consider introducing universal service obligations for private telecommunications providers. However, care needs to be taken to ensure that these regulatory interventions do not discourage private investment.

Encouraging investment in mobile networks in low income countries in particular can be a powerful driver of digital financial inclusion, underpinning female entrepreneurship and participation in the digital economy. Given how critical access to access to connectivity is to functioning in the information society of the 21st century, policy makers should view access to connectivity in a similar way as they view access to other essential services such as electricity and water when considering welfare adequacy and consumer protections such as financial hardship provisions. The most efficient way to address affordability is via the tax and transfer system, and there may be merit in reviewing the adequacy of welfare arrangements to ensure that they are keeping pace with the costs of connectivity. Policy options that support low income individuals, women and household secondary income earners to participate in the labour market, such as earned income tax credits, are also well adapted to supporting participation in the 'gig' economy and the future of work.

Our results also indicate a positive relationship between maintaining a free and open internet, internet use and female workforce participation. The free flow of data online is a critical enabler of participation in global value chains, and opportunities for trade and employment in the future of work. Data flows are important not only because they underpin trading relationships, but also because they provide women with access to knowledge and digital skills to improve their productivity and employment. The free flow of information also allows people to access information that may challenge traditional ideas about the appropriate role of women in society. It can also facilitate access to information concerning positive role models of women in the technology sector for example, which may help encourage women to pursue digital careers. Respecting the free flow of data online in domestic regulation, and advocating for the benefits of the open Internet in international trade negotiations and diplomacy can be important enablers of reducing the gap in workforce participation between women and men in the Indo-Pacific region.

Skills and entrepreneurship

Women also face a skills gap, preventing them from fully participating as either consumers or producers of digital technologies and financial services. Globally, women make up fewer than 20 per cent of the ICT workforce; 9 per cent of ICT sector CEOs; and only 6 per cent of app developers (ITU, 2016). Given that 95 per cent of jobs now have a digital component (ITU, 2012), it is essential to equip young women with the digital skills and competencies necessary for them to succeed in the digital economy.

Policymakers should consider expanding national primary and secondary curricula to incorporate coding, computational thinking and other digital skills.[ii] Extracurricular activities aimed at enhancing digital skills for young women and promoting digital careers should also be encouraged.[iii] Governments can also encourage partnerships between industry and secondary schools to improve STEM related vocational pathways for young women.[iv] Alongside a greater focus on STEM skills, curricula should also foster creativity, and the development of interpersonal and uniquely human skills that complement rather than compete with digital technologies.

Globally, only 18 per cent of computer science (CS) graduates are women (AAUW, 2015). However, evidence is emerging about a range of interventions that can significantly increase female entry and graduation rates in CS and information technology (IT) degrees. For example, under the Building, Recruiting and Inclusion for Diversity (BRAID) initiative in the United States, each BRAID school commits to undertaking a range of evidence-based actions modelled on the example set by BRAID

Beacon schools.[v] Results from BRAID Beacon schools to date have been impressive (Table 3), with schools implementing BRAID commitments experiencing a 2.3 per cent increase in the representation of women in CS studies from 2014 to 2017.

Table 3: BRAID Beacon schools improvements in female representation

School	Years	Change in Representation	Unit of Measurement
Cal Poly-SLO	2008-2016	8% to 27% (Computer Science) 9% to 29% (Software Engineering)	Women admitted to programs
Harvey Mudd College	2006-2016	12% to 47.5%	Women majoring in computing
University of British Columbia	1997-2016	16% to 32%	Women majoring in computing
University of Washington	2007-2015	19% to 33%	Women majoring in computing

Sources: Reproduced from https://anitab.org/braid-building-recruiting-and-inclusion-for-diversity/.

BRAID commitments to date have included:

- Modifying introductory CS courses to engage more inexperienced students, with women overrepresented in the inexperienced cohort;
- providing outreach to primary and high-school teachers to develop their digital and computer science teaching skills;
- sponsoring summer camps and after-school programs to encourage girls to engage in CS;
- establishing student groups and mentoring programs for women in computing;
- promoting positive female role models in computer science and STEM;
- offering inter-disciplinary majors combining CS with other fields based on evidence that women prefer to combining CS studies with qualifications that address a broader social betterment objective;
- based on evidence indicating that exposing undergraduate students to research experience in STEM fields increases graduation rates, BRAID schools are encouraged to support summer STEM research opportunities for undergraduate students who have completed one or two STEM courses;
- increasing female faculty members; and
- implementing "flipped learning" and other active learning and peer instruction methodologies.

As the above list indicates, policies to reduce the digital gender divide in computer science qualifications needn't be costly, or out of reach for developing economies. They often involve simply changing the way existing classroom activities are structured or run. For example, Booth, Cardona Sosa and Nolen (2013) show that single sex introductory classes for technical subjects, like STEM subjects, can significantly improve female performance and university course completion rates, at no cost and with no adverse consequences for male students.[vi] Policy-makers can also encourage national universities and research institutions to sign on to initiatives such as the Athena SWAN (Scientific Women's Academic Network) Charter and support other national initiatives that promote gender equality and diversity in STEM fields.[vii]

Lifelong learning is also critical, with Singapore's SkillsFuture platform providing an excellent example of how governments can equip people of all ages with the skills necessary to participate in a rapidly

evolving digital economy. Under this initiative employers provide input on the skills they believe workers will require over the next three to five years. Individuals can then learn these skills in short, industry and digitally relevant courses, while they are working or undertaking study. The scheme provides a coherent framework for micro-skilling and lifelong learning, with course completion providing individuals with recognised qualifications in skills relevant to the digital economy. The initiative is heavily subsidised by employers, and the Singapore Government provides an opening credit of S$500 and periodic top ups into individual learning accounts to apply towards courses.

Policy-makers in the Indo-Pacific should also consider developing policies or strategies that support women who wish to become digital entrepreneurs. For example, Australia's *New Enterprise Incentive Scheme* (Department of Employment, 2017) encourages women to participate in digital careers by supporting job seekers to become small business owners. This program can help women participate in the digital economy, for example by starting a small business that trades online using digital platforms. The World Bank *Women Entrepreneurs Finance Initiative* (We-Fi), of which the Australian Government is a founding partner, will enable more than US$ 1 billion in financing to improve access to capital and technical assistance for female entrepreneurs, including those engaged in digital entrepreneurship.

Norms

Our research points to the relevance of country specific heterogeneity reflecting time invariant cultural, religious and other value systems in determining female workforce participation in the Indo-Pacific. This reinforces the fact that the challenge of bridging the digital gender divide is not simply a matter of providing equal access to digital technologies or digital skills; it is also about changing community attitudes and norms.

Women consistently report lower levels of self-confidence in their computing and STEM ability than men, however high school academic results actually show that women typically outperform men in these fields (Sax and Lehman, 2016). The stereotypical image of a person interested in studying or working in information technology as a 'geek', 'hacker' or 'gamer' can also be unappealing to many women. Therefore, policymakers should consider initiating national advocacy campaigns and events that promote positive female role models in the digital economy.[viii] Transparency regimes for gender pay and participation gaps can also help shine a light on economically costly discrimination.

A further challenge to higher levels of female participation in the digital economy is that digital technologies can be used to harass and perpetrate violence against women and girls, creating an impression that the digital economy is not a safe space for women. Policy-makers should consider supporting risk-based policy interventions that aim to lower the probability of cybercrime against women and girls taking place, as well as reducing the impact of these crimes on victims. This may include initiatives that enhance women and girls' resilience and ability to protect and defend themselves in a digital environment, such as digital literacy programs, and promoting awareness of support networks and counselling services for victims of cyber violence.[ix]

Policy-makers should also review and reform of national legislation on violence against women to include technology-related forms of violence. Fundamentally, human rights and the rule of law should apply online as they do offline. This means enacting and enforcing laws that make it illegal to use the Internet to threaten, harass or offend women, and cooperating in international enforcement actions given the global reach of the Internet.[x] Governments should also continue to place pressure on social media and other digital platforms to immediately takedown extremist and unlawful content, including that intended to threaten and intimidate women.

Socials norms also influence policy settings that have a critical role to play in supporting female participation in digital careers. At a fundamental level workplace relations policies should support flexible work practices, and promote a non-discriminatory workplace, including with respect to pay and career progression. Evidence from the OECD (2013) suggests that reducing effective marginal tax rates on household secondary income earners, supporting access to childcare, and the provision of child and family benefit payments all support higher levels of female participation. However, care needs to be taken in the design of parenting leave arrangements to ensure these do not act as a labour market "off ramp" for women.

Governments also have a role to play in changing perceptions about women in technology leadership positions, and ensuring that women are more highly represented in executive positions and board appointments. Internationally, the ITU EQUALS initiative promotes leadership opportunities for women in the digital workforce and women's entrepreneurship, and aims to work with private sector and governmental partners to facilitate more women in leadership roles (Equals.org, 2017). In Australia, the Male Champions of Change in STEM Group drawn from male leaders of technology companies and research institutions seeks to use its individual and collective influence to achieve a significant increase in the representation of women in leadership positions in STEM industries and research.

Data

A final barrier to women's participation in the digital economy is the lack of gender-specific ICT data in national statistics which can make it difficult for policy makers to apply a gender lens in evidence-based policy development and evaluation. A better evidence base is urgently required to help inform the development and evaluation of policy actions to bridge the digital gender divide. More broadly, national macroeconomic statistics are in need of an urgent upgrade to provide better visibility of the impact the digital economy is having on productivity and employment. Better labour market data is also required to understand trends in contingent work arrangements and 'gig' employment.

Subject to capacity, countries in the Indo-Pacific region should consider collecting sex-disaggregated ICT statistics to better identify participation or usage gaps between the sexes. For more developed economies, more regular time-use surveys are a critical vehicle to capture information on women's aggregate participation in market and non-market production, including in the context of the digital economy. Initiatives such as these will improve the evidence base for policies aiming to make the digital economy more inclusive. Countries in the region should also consider increasing their engagement with multilateral efforts already underway to improve the measurement of the digital economy in macroeconomic statistics.

Conclusions

On a country-by-country basis, the labour force participation gap between men and women in the Indo-Pacific has been narrowing at a time of rapid growth in Internet usage and digital connectivity. Perhaps unsurprisingly, we find a positive and statistically significant relationship between internet use and female labour force participation in the Indo-Pacific, even after controlling for a number a variables commonly associated with female participation, time and country specific fixed effects. The magnitude of the association is economically significant, with the most conservative estimate suggesting that, on average, growth in internet use has been associated with two-thirds of the increase in female workforce participation in the Indo-Pacific since the year 2000. We find some evidence of a causal relationship between Internet use and female participation using an instrumental variables approach. The use of state control of the Internet as an instrument for Internet use also points to the important role that the free flow of information online can play in supporting a thriving

digital economy, and indirectly higher levels of female workforce participation. Despite the positive association between digitisation and female workforce participation, a number of barriers remain which are preventing women from fully participating in the digital economy. The G20 Taskforce on Digitalisation is focused on addressing the access, skills, normative and evidentiary barriers to higher levels of female participation in the digital economy, and better job quality for women in the future of work.

Appendix

Table 1: Summary Statistics

	World			Indo-Pacific		
	Total Obs.	2015, Mean	Change 2000 to 2015	Total Obs.	2015, Mean	Change 2000 to 2015
Female participation	3,077	52.2	2.0	1,207	48.7	1.8
Participation ratio (female to male)	3,165	71.2	4.2	1,216	64.3	3.2
GDP per capita, $PPP	3,083	$18,711	$7,706	1,190	$19,920	$7,955
Life expectancy, years	3,085	74.3	5.0	1,155	76.5	4.2
Fertility rate, births per woman	3,083	2.8	-0.5	1,159	2.5	-0.6
Education expenditure (proportion total government expenditure)	1,669	16.2	1.2	627	16.4	1.2
Trade, per cent of GDP	3,058	88.6	3.0	1,151	84.0	-2.6
Services share of GDP by value added	2,689	60.3	5.2	976	58.7	5.7
Agricultural share of GDP by value added	2,820	12.2	-3.5	1,023	10.7	-6.4
Broadband, subscriptions per 100 pop	2,342	13.3	12.7	927	10.1	9.3
Mobiles, subscriptions per 100 pop	2,867	106.9	90.2	1,100	113.2	100.9
Internet usage, per cent	2,840	48.5	39.4	1,100	48.5	40.4

Source: World Bank, International Telecommunications Union (ITU)

Table 2: First Stage Regression

Dependent variable: Internet use (2008, 2010-2014)								
Eq.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	2.24 (0.38)	84.66*** (4.36)	20.33 (0.94)	-	73.14 (1.19)	-393.33* (-2.64)	-445.20*** (-3.46)	-439.96*** (-3.75)
State control Internet	0.29 (1.87)	0.30* (1.96)	0.33* (2.48)	0.34** (2.57)	0.38** (2.62)	0.51 (1.77)	0.60* (2.04)	0.52* (2.13)
Access foreign info	-0.19** (-2.59)	-0.20** (-2.70)	-0.08 (-1.09)	-0.11 (-1.42)	-0.11 (-1.94)	-0.22 (-1.13)	-0.25 (-1.26)	-0.18 (-1.09)
GDP per capita		-0.00 (-1.46)	0.00 (0.80)	0.00 (0.58)	-0.00 (-0.24)	0.00 (0.54)	0.00 (0.38)	0.00 (0.92)
Trade share			0.20*** (7.12)	0.20*** (7.38)	0.19*** (6.58)	0.27*** (4.69)	0.22** (3.41)	0.24*** (3.78)
Female life exp.				-2.06* (-2.10)	-0.94 (-1.28)	4.29* (2.32)	4.89** (3.04)	4.53** (3.10)
Fertility rate					19.77*** (4.66)	40.65*** (7.81)	44.71*** (9.54)	39.72*** (8.13)
Educ. Exp.						-0.70** (-2.94)	-0.64* (-2.44)	-0.72** (-2.91)
Ag. share							0.22 (0.82)	0.24 (0.64)
Services share								0.63* (2.17)
Country dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time dummies (p>F)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
N	300	300	294	294	294	193	186	186
R^2	0.97	0.97	0.98	0.98	0.98	0.99	0.99	0.99
Wald test all ($p>\chi^2$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wald test IVs ($p>\chi^2$)	0.03	0.02	0.04	0.04	0.03	0.07	0.04	0.03

Notes: * p<0.05; ** p<0.01; *** p<0.001. z statistics are in brackets. Wald tests are on the null of all parameters being equal to zero, and parameters on state control of the Internet and access to foreign information both equaling zero.

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[i] In 2016 less than 50 per cent of countries globally incorporated relevant references, actions and goals to address gender equality in national broadband policies (Australian Government, 2017).

[ii] Consideration should also be given to the need to include gender-appropriate teaching material in these curricular, and provide training and support to teachers to enable them to deliver a digital skills curriculum.

[iii] For example, as part of its $A13 million Women in STEM and Entrepreneurship grant program under the National Innovation and Science Agenda, the Australian Government is supporting initiatives such as Girl Geek Academy, which encourages early participation in STEM by teaching 5-8 years girls to code (National Innovation and Science Agenda, 2017).

[iv] For example, the Australian Government is investing $A5.1 million to pilot two Pathways in Technology (P-TECH) sites to support the building of STEM capability and improving the quality of vocational pathways available for young people, including young women (Skilling Australia Foundation, 2017). The Australian Government has also committed to expanding the P-TECH pilot to 12 additional sites across Australia. P-TECH is an innovative approach to education-industry collaboration, which was adapted from the US Pathways in Technology Early College High School (P-TECH) model using existing qualifications and operating under current education system requirements. Key features of the program include: collaboration between education and industry sectors; innovative curriculum design; hands-on workplace experience for students; industry mentoring and support for students; and industry supported pathways for students to successfully transition to post-school study and/or work.

[v] The Initiative is financially supported by Facebook, Google, Intel, Microsoft, the Computing Research Association and the National Science Foundation in partnership with participating institution.

[vi] Booth, Cardona Sosa and Nolen (2013) suggest that enhanced female performance is attributed to a lowering of stereotype effects where women inhibited by culturally driven norms about the appropriate mode of female behaviour—avoiding risk—find it easier to make riskier choices once placed in an all-female environment. An all-female group may also facilitate the formation of friendships within a faculty environment that is disproportionately male. These friendships may enhance the confidence of these women and facilitate the formation of networks, leading them to feel more comfortable in making riskier choices than women in co-ed classes.

[vii] The Athena SWAN Charter is a highly successful evaluation and accreditation program aimed at enhancing gender equity for STEM fields (Equality Challenge Unit, 2017). Through Bronze, Silver and Gold Awards, the charter recognises excellence in employment practices that advance and promote the careers of women and gender minorities in STEM subjects. Currently, 137 institutions belong to the UK Athena SWAN Charter. Science in Australia Gender Equity (SAGE), the Australian pilot of the Athena SWAN Charter, has adapted the UK processes to the Australian context, running training workshops on gender equity and providing accreditation for universities, medical research centres and government research organisations who will participate in the SAGE Pilot.

[viii] For example, as part of the EQUALS initiative, a number of Girls in ICT Day events have been planned to promote ICT studies and careers to girls and young women before they make decisions related to tertiary education, including hands on workshops that introduce girls and young women to coding, mobile apps development and programming robots (ITU, 2017). Girls in ICT Day organisers can also be leveraged to provide coding and mobile app training throughout the year to young women and girls.

[ix] Internationally, the American National Network to End Domestic Violence is a model of best practice. It undertakes research and provides instruction on how to recognise and address technology facilitated abuse, and provides training and support to frontline workers. The Australian Government also funds a range of initiatives to raise awareness about technology facilitated abuse and provide tools for community and front

line services on how to identify it and provide victims with support such as *1800RESPECT*, *ThinkUKnow* and *eSafety Women*.

[x] Policy-makers should also consider comprehensive policy responses to prevent the non-consensual sharing of images online and laws outlawing the use of the Internet to prepare or plan to cause harm to, procure, or engage in sexual activity with children.