Is Technology Polarizing the Australian Work Force?
Presentation script

Motivation
The second half of the 20th century has witnessed tremendous change for Australian workers. Since 1973, average real incomes have approximately doubled, and the number of jobs available in the economy has increased by over three million. These statistics paint a rosy picture of economy growth over the last 40 years. But these changes were not evenly distributed: top percentile wage growth far outstripped that of lower-wage earners. While income inequality in Australia actually fell somewhat between the 1950's and 1970's, for the last 30 years, it has risen consistently.

* This graph summarizes the change in real income, across earnings percentiles, for full-time workers. Between 1981/82, and 2009/10, the real income of full-time workers in the bottom income percentiles remains at much the same level as what it was 30 years ago. Top percentiles have seen tremendous growth.

There is a large literature studying the rise of wage inequality in Australia. Empirical studies have confirmed that both individual-level and household-level inequality have been rising since the 1980s. Over this 30-year period, it is unlikely that any single labour force development could completely explain the rise in inequality. The work force has become much more flexible, the union membership rate has decreased, businesses have made greater use of out-sourced labour, and more broadly, the rise of global business has had a profound influence on the types of labour that firms demand.

For my thesis research, I focus on just one of these determinants: the rapid introduction of information and computer technology to the work place, brought about in part by its incredible decline in cost over the post-war era. *

This chart, taken from a 2006 paper by the economist William Nordhaus, plots the real cost of computations per second as computing technology has advanced. The vertical axis is a logarithmic price scale; the straight downward-sloping line of points illustrates an exponential decline in the cost of computation. Nordhaus estimates that, between 1947 and 2006, electronic computation became 7.4 *trillion* times cheaper than comparable manual calculations.

Over the same period, the cost of data storage also fell at exponential rates, paving the way for the development of novel business applications. And as computers have become cheaper and more useful, firms have found ways to use them profitably. Australian firms' annual investment in computers grew from 26M in 1981 to 14B in 2012, in real terms.

The technological shock that resulted from this trend has profoundly shaped our economic lives. There are few economic transactions today that are not mediated, in some way at least, by electronic computation and telecommunications. As students and researchers, our daily activities have also been shaped by the technologies that computation has enabled. This paper was written using a laptop and and Internet connection; you couldn't do that a generation ago. The same can be said for almost every occupation, in almost every industry. Economists have paid considerable attention to the way in which technology may have changed the productivity, wages and demand for labour. But most of this research has been conducted in overseas labour markets, in particular in the United States. Since Australian firms operate, for the most part, under similar technology US and European firms, we should observe similar trends in the Australian labour market.

The goal of my thesis research has been to try and quantify the impact that technological change may, or may not, have had the composition of the Australian work force, and its wage distribution. In particular, we focus on findings from overseas markets that technology may have a `polarizing' effect on jobs and wages, which we'll discuss later.

* My thesis project is organized in three parts, and this talk will follow the same structure. The main analysis, which I'll touch on last, wasn't ready in time to present here. So instead we'll talk about some of the initial exploration. Our first step is to look at one standard model used in the literature to study the impact of technological change, the model of skill-biased technical change, which considers technology to be complementary to high-skilled labour. *

We then consider an alternative approach, in two steps, which focus on occupations. We consider the relationship between ICT investment and wages, * and then we will discuss the third (and ongoing) stage of the research, that looks at the task content of occupations, and how those tasks might alter the impact of technological shocks on the demand for labour.

Skill-biased technical change

[*] A leading explanation for this divergence of incomes is that skilled work and new technologies are complements in production, or factor augmenting. This idea, developed by Tinbergen and many many others, suggests that new workplace technologies disproportionately complement highly-skilled technical and managerial jobs, relative to low-skilled manual and service jobs.

This model assumes a competitive economy with two different, imperfectly substitutable types of labor: high-skilled and low-skilled. Workers don't all have to be identical, we can simply think about the amount of labour each group provides. But we do assume that both groups of workers are paid the same wage. * Mathematically, production in this economy is governed by a constant elasticity of supply aggregate production function, and we will assume the elasticity of substitution is greater than one. Again, this production function simply captures the fact that both types of labour are needed in production, and that one is an imperfect substitute for the other. We need researchers and scientists, but we also need truck drivers and labourers, too; it would be inefficient to try and substitute labourers with scientists or vice versa.

In the production function in the slides, the A terms represent the factor-augmenting technology associated with each type of labour. We're thinking about technology that makes one of the types of labour more productive---for the sake of argument, an email system that allows a researcher to confer more effectively with colleagues---which we can analyze what happens with an increase in one of the A parameters.

The skill-biased technical change story claims that technologies of the sort we're talking about here---electronics, computer technology and the like---disproportionately affect the productivity of high-skilled workers, but not low-skilled workers. While email system increases the productivity of researchers and other professionals, our high-skilled workers, under this story it's of little use to low-skilled workers such as labourers and truck drivers. If this is the case, we say the technology exhibits *skill bias*.

[*] We won't develop the model mathematically in this short presentation, although the paper does include a few more details. Instead, we'll state the model's general predictions, then look at some data. For our purposes, we are interested in two claims the model makes about relative wages: first, that skill-biased technological change should *never* cause low-skilled wages to decrease, and second, that technological change should result in a monotonic wage increase across the skill spectrum.

Under this explanation, the variable we're interested in the difference in wages paid to high- and low-skilled workers. In the United States and elsewhere, the wages paid to college-educated workers has been increasing for decades. This difference, called the skill premium, increases since high-skilled workers become relatively more productive, and so in a competitive economy, workers are paid according to their marginal product.

But, importantly, as wages for high-skilled workers increases, the wage paid to low-skilled workers should never decrease. Remember high- and low-skilled workers are complements in production; if high-skilled labour is more valuable, then so too is low-skilled labour.

There is evidence that, in the United States at least, an increase in the demand for skilled labor, relative to its supply, has resulted in higher wages for skilled occupations. There is also strong empirical evidence for skill-upgrading; since rational agents in this model will seek to acquire higher skills, in order to exploit skill-biased technology. We've seen this both in Australia and overseas.

Data

To bring the SBTC model to the data, we employ the Survey of Income and Housing, a hierarchical clustered household survey conducted every couple of years by the ABS. The survey provides a breakdown of respondents' labor and non-labor income sources, as well as data on age, educational attainment, hours worked and industry and occupation. In some of the surveys, we get occupational information, too. We obtain survey micro-data as confidentialized unit record files (CURFs).

To facilitate fair comparisons between years, we need to eliminate effects arising from mechanical, demographic shifts. Between 1982 and 2010, the number of women in the work force has increased dramatically, and the same period has seen an evolution of the educational and age composition of the work force, and the rate of casual and part-time employment has increased. Following Daron Acemoglu, we therefore include only full-time workers for whom labor forms the primary source of income. We further composition-adjust each survey to match 2010 demographics by linearly scaling the survey selection weights for each age group/sex/educational group cell.

Does SBTC fit the Australian data?

[*] If SBTC explained the widening of the income distribution, we would expect to observe the skill premium increasing with time.. The chart shows the log skill premium since 1981 for the USA. This trend in the data fits the model. * In Australia, however, a corresponding growth in the premium for tertiary qualifications has not been observed. Unlike the United States, the log skill premium for Australia has not been increasing; in fact it's remained remarkably steady.

There are many reasons why this might be. Maybe the relative skilled labour supply is moving right. Rather than any fundamental differences in the nature of the demand for skills, Coelli attributes this difference in Australian workers to differences in the nature of Australian educational qualifications. In Australia, University degrees are available to a wider range of candidates and for a wider range of disciplines than those who would traditionally have undertaken university studies in the United States. As a result, tertiary educational attainment may be a poor proxy for `skilled' work in Australia. Which is annoying, really, because educational attainment is a really convenient variable, and so easy to model.

Another proxy for skill are earnings percentiles. If we imagine that 'skills' as allocated according to some distribution, we can imagine that median wage earners as being about in the middle of the skill spectrum. Under this assumption, those in the 5th percentile can be considered low-skilled, and those in the 95th as high-skilled.

[*] The shows the cumulative composition-adjusted changes in log real wage for these three earnings percentiles, for males and females. For comparison, I've normalized log wages for all three groups to zero in 1981. This chart shows that, for both males and females, top wage earners' real incomes have increased the most, followed by the median, and then bottom-percentile earners.

But now notice that earnings increases have not always been monotonically increasing for median and low-income workers. The skill-biased technical change model claims that, even if technology exhibits skill bias, wages for all skill groups should increase monotonically. Over the period 1981-82 to 2009-10, wages at the top percentiles increased more or less steadily, but the same is not true for the lower percentiles. Indeed, for all of the 1990s and much of the 2000s, cumulative real income growth from 1981-82 was negative for many workers.

To get a more detailed view of the `skills by income' proxy, we can compare changes in 1981-82 and

2009-10 incomes, by percentile. Again, I've centered the median at zero for easy comparison. Once again, if you grant that the 1981-82 income percentile can be considered a proxy for skill, then it is apparent that, over this period, wages more grew for high-skill individuals much faster than for low-skill individuals.

On the right-hand-side, the changes in the male wage profile is exactly what we expect to see. The higher income percentiles experienced greater income growth, and vice versa.

But have a look at the wage change profile for females. First, it's not the same profile as men--but it should at least be similar, because we've composition-adjusted for things like age and education. But it is certainly *not* a monotonically increasing function. Something funky is happening at the bottom of the wage spectrum; there seems to be some kind of polarization occurring in the wage spectrum.

Granted, this is only a rough sketch from a macro perspective, and we can't pick up movements over time between percentiles here.

But the puzzle is this. If education is a good proxy for skill, and the skill-bias story is reasonable, we would certainly expect an education premium to be driving that change. But it doesn't seem to be

[*] Let's sum up what we've found so far. Mind the typo in the slides; should say there's no clear *increase* in the college premium in Australia. So *if* general skill, along with biased technology, is driving the inequality trend, then we certainly aren't seeing it in educational attainment.

* We also observe non-monotone wage growth, both across the skill spectrum, and over time. Our model would have us believe that technology is factor-augmenting -- that is that it's always complementary -- and so this should never be observed.

* And finally, we see a puzzling difference in the wage growth patterns of males and females.

On this last point, there's one clue in the data which is rather suggestive. Let's have a look at the trends in employment by broad occupational group, over time, for males and females.

[*] First, notice that, for men, on the right-hand-side, the occupational shares are pretty much horizontal lines. There is not a great deal of occupational change. But on the left-hand side, there is a marked decline in the proportion of women undertaking clerical work, and a marked *increase* in women undertaking professional and managerial work.

But the fact that men and women have tended to undertake different kinds of work gives us an interesting natural experiment. The proportion of women involved in low-skilled work seems pretty static, and the fraction in high-skilled work is clearly increasing. But middle-skilled jobs, clerical and sales work, appears to be sharply declining. Maybe that's what we're seeing in the bent wage change profile. And where is all this clerical employment going, anyway?

These changes have been observed in the United States and Europe, too, albeit for both males and females. This polarization of the work force has simultaneously manifested in wages and in jobs: both wage growth and growth in the level of employment are concentrated in high-skill jobs, and to a lesser extent, the bottom end of the skill spectrum. Middle-skill jobs have stagnated since the 1990s, both in terms of remuneration and level.

If technology is associated with this trend, it looks like we need a more nuanced view of technological change. Leaning on a 2003 paper by Autor Levy and Murnane, we might ask, is technological change necessarily complementary to all types of labour? Or could it actually be a complement for some, and a substitute for others?

An alternate approach: `jobs' and `tasks'

[*] Remember the simple neoclassical production function we used earlier? We imagined labour and capital being magically turned into output, abstracting away from the details of how it actually works. * The task approach adds a step, and instead thinks about the individual ‘tasks’ that a job might entail, and how those tasks might produce output.

[*] This is a very subtle distinction, but it has powerful implications. Remember, what we’re searching for is some kind of polarizing effect: some mechanism by which technology can affect some jobs and not others.

The key insight here, is that computers, as sophisticated as they are, are in fact pretty limited. They can only replace some kinds of jobs. They are only capable of performing a very limited set of simple activities. They’re great for `routine’ tasks that require calculation and simple symbolic manipulation, and don’t make mistakes like we do. Yet, any task that requires abstract thought or physical coordination, however elementary it may appear to a human worker, is not yet possible with a machine. We use `routine’ in a very particular sense here---many occupations which we might colloquially consider `routine'---such as stacking shelves or driving a taxi---require a degree of perception and motor control out of reach for a computer, and for our purposes are `non-routine.' In these areas, for the moment at least, human workers enjoy a competitive advantage, and technology is not yet a substitute.

So middle-skilled work -- the clerical and sales workers we identified a minute ago -- are exactly the kinds of jobs we expect to see disappear.

[*] Thus computing capital is a complement to some kinds of task-performing labor, and a substitute for others. Autor Levy and Murnane show that, in the United States between 1960 and 1998, computerization led to a substitution in the observed levels of employment, away from routine tasks and toward cognitive tasks. Non-routine tasks, on the other hand, may improve, rather than replace, the efficiency of human workers.

[*] To test this pattern for Australian data, we can augment eq:prod by introducing a third type of labor, to represent middle-skilled work. We also introduce computer capital as a substitute in production for medium-skilled labor, and a complement in production for high-skilled workers.

This production function is a bit complicated, but bear with me. On the left, we have low-skilled labor, as before. In the middle, middle-skilled labour and computer capital, which are perfect substitutes. And, on the right, high-skilled work and computer capital, as complements.

* This toy model gives us some useful comparative statics. If we exogenously increase computer capital, then the wage share paid to middle-skilled workers decreases, but increases for high-skilled workers.

The simple test we perform uses data on 18 industry groups. We use aggregate employment data, for three groups of occupations, corresponding to high-, medium- and low-killed work. We also use national accounts data on ICT capital.

What we want to know is, if an industry ramps up computer capital, then what happens to the wage share paid to each group?

Don't worry -- there won't be any regression results. That's partly because that's boring in a presentation, but mostly because the results aren't terribly strong or robust with this few observations. Let's look at a picture instead.

[*] This chart shows the change in wage share on the vertical axis, and ICT electronic and electrical equipment investment on the horizontal axis. For low- and high-skilled labour, the relationship is upward-sloping. But for middle-skilled labour, it's downward sloping, just as our model predicts.
When we assume a linear relationship, we get that over a seven-year period, a 10% increase in electrical and electronic equipment capital is associated with a decrease in the wage share of middle-skilled workers of around 20 percentage points, whereas it is associated with a relative increase in the wage share of high-skill workers versus low-skilled workers.

[*] Of course, these results should be interpreted with extreme caution. First, we only get the wage share here, and not the wage, which is a pity since what we're interested in is the returns to each individuals' work.
* It's silly to think capital investment is exogenous, although its price might be. There's no natural experiment that's obvious to me, and nor is there a clear instrument for ICT expenditure. So this relationship should be interpreted simply as a correlation.
* And we only have a few observations, so our tests have low power.
* If we include other measures, like software or peripherals, the relationship gets more complicated, and it's hard to see exactly what's going on.
* I'm not sure about the best way to compare ICT capital costs from one period to another. Clearly, $1000

of computers gets you more today than it did in the 80s.
Nonetheless, the preceding analysis supports the more `nuanced' view that occupational tasks, rather than other human capital variables like education, are important determinants of the evolution of the wage distribution.

More sophisticated approach

[*] The evidence given above is only informal, but it is highly suggestive that polarization is likely occurring.

The goal of the next part of this research project is to be a bit more rigorous. One promising approach in the literature, proposed by Firpo, Fortin and Lemieux. They think about the labour market as a Roy model: basically, people self-select into occupations based on comparative advantage. If demand for an occupation's labour decreases, we can measure this by looking at distributional statistics for that occupation.

* To skirt the problem about ICT investment, we instead look at qualities of the job itself. Is the job routine? Then it'll probably be replaced by a computer. Is the job off-shorable? It probably will be.

[*] The data we have available is pretty exciting. In addition to the census for occupations data, we have access to the US Department of Labour job classification scheme. This scheme includes a really detailed set of task measures -- on hundreds of variables -- of all the activities involved in performing that job. The data were constructed using expert surveys, and provide a very rich source of information about the activities that workers in each occupation actually undertake.

[*] Here's a quick data sample. For the work activity, "analyze data", the occupations economist and surgeon both score highly (6.58/7 and 5.49/7, respectively.) But for the work activity, "Handle moving objects," surgeons score 3.62/7, and economists score only 0.54/7.

The great thing about this is that these scores allow econometric models to "see" the properties of jobs, and provides us with a rigorous way of working out whether routineness or offshoreability--both outcomes of ICT investment--are responsible for the decline in a job's number and wage.

This process is not without its headaches. We had to map all the Australian job codes to the US ones. We've had real trouble getting data with detailed occupational variables, too. Sadly, although data were collected at the four-digit level, we have had to accept two-digit occupational codes because the ABS is concerned about the privacy of its survey respondents. This is particularly upsetting, since my painstakingly-compiled mappings go all the way down to four-digit level. One solution may be to use census data; however, income levels in the census are binned, rather than continuous, which provides some further issues with our choice of quantile regression estimators.

I’ve certainly learned a lot about research in the process of doing all this -- and one painful lesson is that data concerns like these are going to be the bane of my existence as a researcher for many years to come.

To summarize, the results I’ve collected to date are suggestive of the same polarization process that has been reported in other labour markets, and it does seem to be correlated with ICT investment. Hopefully, our further research on relationship between job tasks and income will paint a much more detailed picture about what is driving these changes, and perhaps also give a perspective into what trends might be driving inequality.

The results obtained to date paint a picture of a work force which is constantly evolving as new technologies become more readily available. This work has important implications for both education policy and the broader inequality debate. If whole categories of jobs are in the process of fading away, are we equipping the next generation with the skills they need to flourish in tomorrow's workplace? And if labour-saving technology is responsible, at least in part, for the upward trend of income inequality, what should be done now to ensure that workers of the future are not left behind?