The UK and Western Productivity Puzzle: Does Arthur Lewis Hold the Key?

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Abstract

A new explanation for the UK and developed world productivity puzzle is proposed which grafts the Lewis (1954) model onto a standard Solow growth model. What is called here the neo-Lewis model is identical to the Solow model in good times. But in bad times foreign demand for a country's exports is constrained below potential supply. This makes labour productivity growth depend negatively on the growth of labour input and positively on the growth of export demand.The predictions of the neo-Lewis model are tested on data for 23 countries (20 EU and 3 non-EU) and find support. It is also argued that the neo-Lewis model can explain the fall in TFP growth, in the UK and elsewhere, after 2007. This proposition also finds support when tested on a larger sample of 52 countries.

Labour productivity has barely grown in the UK since the last boom ended at the beginning of 2008. The decade or more of productivity stagnation since then is even more surprising given that before the crisis the UK's productivity growth was one of the highest amongst the advanced economies. The Office for Budget Responsibility (2017) has recently estimated that up to 2017 the decline in labour productivity growth relative to the pre-crisis trend has already caused a loss of about 21 per cent in GDP

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per hour. By contrast the OECD recently projected that after Brexit the UK's GDP per head will be 3 per cent lower by 2030 than it would have been if the UK remained in the EU (OECD 2016, central scenario). The productivity puzzle is therefore the greatest challenge facing UK economic policy, and far larger than Brexit.

On the other hand, the performance of the UK labour market has been excellent. True, as the Great Recession began unemployment rose rapidly above its pre-crisis level but it has since declined and at 4.0 per cent in 2018Q4 is now lower than at the peak of the boom. Employment too took a hit during the recession itself, which saw a fall in GDP of over 6 per cent from the peak to the trough, but it has subsequently (2009-2015) grown as fast as during the boom. In summary, an excellent labour market performance has accompanied an unprecedentedly poor productivity performance. This is the twofold puzzle of the UK economy since the Great Recession.

The UK productivity puzzle has been much discussed and much reviewed (Oulton 2016a; Haldane 2017; Tenreyro 2018), but without any consensus so far being reached. Here I propose a new explanation based on insights gained from the work of Arthur Lewis. Briefly, the argument is as follows. After the recession began, many countries, particularly in Europe, suffered from a deficiency in foreign demand for their exports. This situation has persisted into the recovery period, after GDP stopped actually falling, The slower growth of exports led to slower growth of GDP. The effect of this on labour productivity depended on the nature of labour market institutions.

In the UK, for example, labour input has continued to rise at the same rate after the crisis as it had done before. This was possible because of the flexible labour market which allowed workers to price themselves into jobs. With the same growth of labour input but slower growth of GDP post-crisis, the growth rate of labour productivity necessarily fell. Both before and after the crisis the bulk of the increase in labour input was due to immigration. In continental Europe by contrast labour markets are less flexible. So the growth of labour input was constrained; in fact labour input declined in most countries. Consequently the slowdown in labour productivity was less pronounced in continental Europe than in the UK.[2]

This explanation puts the blame for

2 See Online Appendix B for discussion of the differences between UK and European labour markets (available at: http://www.csls.ca/ipm/36/Oulton_appendix.pdf).

the slowdown squarely on the Great Recession. However the accepted view now seems to be that continuing low productivity growth has little or nothing to do with the recession. It is instead explained by a decline in the growth rate of TFP which predated the crisis. This decline is partly exogenous, due to the fading effects of the ICT revolution. But it is also partly endogenous, due to weaknesses in the competitive process, which again predate the recession (Bergaud *et al.*, 2014; Fernald, 2015; Cette *et al.*, 2016; Antolin-Diaz *et al.*, 2017). This has been compounded in some countries by failure to adopt the type of structural reforms long advocated by the OECD. These authors have given good reasons for expecting TFP growth to be lower in future than it was in the United States in the glory days of the ICT revolution. And there does seem to be evidence that the competitive process has been weakening; for example, laggard firms seem to have increasing difficulty in catching up to the leading ones (see e.g. Andrews *et al.*, 2015, and Cette *et al.*, 2018).

But this is not the whole story. The collapse in TFP growth, particularly in Europe, is too large to be explained by these forces and moreover the timing is suspicious. Instead, it is argued that the Great Recession itself did significant damage to TFP growth through a number of channels. There is industry-based evidence for increasing returns: an industry's TFP growth rate is higher when the economy is expanding more rapidly (Hall, 1988; Caballero and Lyons, 1990; Bartelsman *et al.*, 1994; and Oulton, 1996). So raising the growth rate of GDP would also raise the growth rate of TFP and consequently of labour productivity.

The plan of the article is as follows. The first section reviews the UK's performance since 2000, compared with other EU and non-EU countries (Australia, Canada, and the United States) over the same period. The second section considers whether the standard growth model due to Solow (1956) can explain the data. This is a reasonable question to ask of the model, at least for the UK, since it assumes full employment which is what we now have. I conclude that the Solow model cannot explain the UK experience since 2007. The third section sets out the Lewis (1954) model of growth with unlimited supplies of labour in a dualistic economy. Section 4 construct what I call the neo-Lewis model in which the spirit of the original model is (I hope) preserved. It turns out that the neo-Lewis model is just the same as the Solow model, except in a "bad regime" when export demand is below potential export supply. In section

5 the neo-Lewis model is confronted with the facts as revealed in the latest (September 2017) release of the EU KLEMS dataset. Then in section 6 the orthodox view of the labour productivity slowdown in the U.K. and elsewhere, namely a slowdown in TFP growth which started before the recession, is critically examined. It is argued that the pre-crisis slowdown is too small to account for the collapse in TFP growth which has occurred since 2007. Instead, I make the case that the bulk of the slowdown, particularly outside the United States, is due to the recession itself. The mechanism is increasing returns, working in reverse. Section 7 concludes.

The UK Productivity Puzzle

The UK Economy: the Twofold Puzzle

GDP and Labour Productivity

GDP in the UK peaked in 2008Q1 and then fell for 5 consecutive quarters. The cumulative fall in output from peak to trough in 2009Q2 was 6.1 per cent. From 2009Q3 GDP began to grow again and growth has been positive in nearly every quarter up to the end of 2018. But in 2017Q3 GDP was only 9.7 per cent higher than at the previous peak nearly ten years earlier, in other words the growth rate of GDP since 2008Q1 was only 0.98 per cent per year.[3]

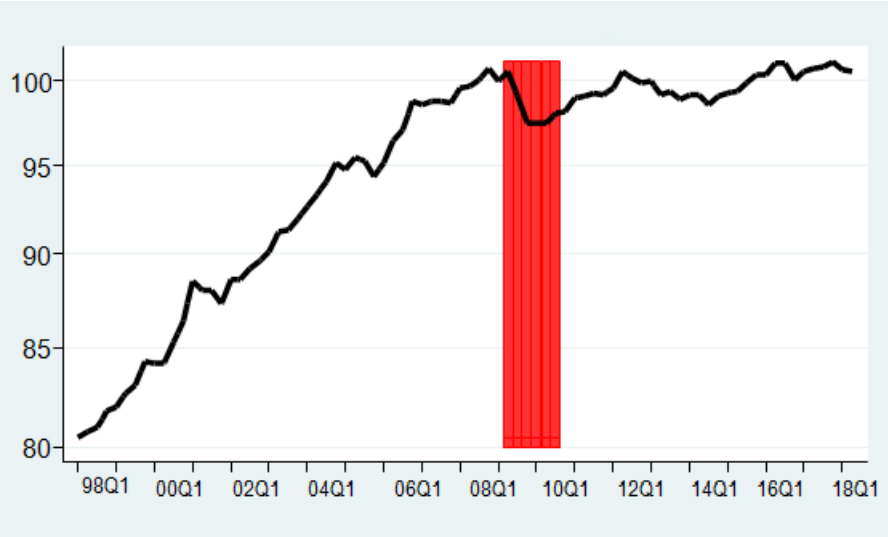
The course of labour productivity since 1997Q1 is shown in Chart 1. Productivity was growing strongly up till 2008Q1. It fell sharply during the Great Recession which was not surprising given the large fall in GDP and experience in previous recessions. What has come as a great surprise is that though productivity growth has been generally positive since the trough it has been so slow that the productivity level in 2017Q2 was still below the previous peak in 2007Q4. So since the peak nearly ten years earlier productivity growth has been virtually zero, even though the recession proper only lasted for 5 quarters. This is the productivity puzzle.

The Labour Market

Unemployment was 5.2 per cent at the end of the boom in 2007Q4. It then rose sharply to peak at 8.4 per cent in 2011Q4. But since then it has fallen steadily to stand at 4.3 per cent in 2017Q3 (Chart 2); in 2018Q4 it stood at 4.0 per cent. This fall in unemployment during the recovery from the Great Recession coincided with a rapid rise in employment which rose

3 Source: Office for National Statistics, https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/pn2, accessed on 10/12/2017. Seasonally adjusted, CVM, £m. Variable cdid: ABMI.

Chart 1: GDP per Hour in the UK, 1997Q1-2017Q2 (Index, 2008Q1 = 100)



Note: Red bar marks Great Recession.
Source: Office for National Statistics

at 0.95 per cent per year from 2000 to 2007. Employment growth slowed slightly during and after the recession, but still grew at 0.85 per cent per year from 2007 to 2016 (Chart 3 and Table 1). Between 2000 and 2016 an additional 4.2 million people entered employment.

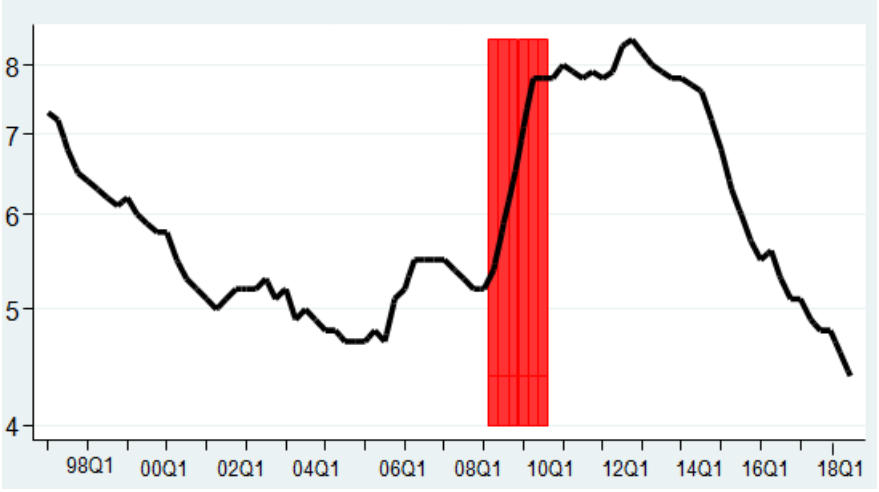
How is it possible for the UK, with a birth rate below replacement level as is typical in Europe, to increase employment at such a rapid rate? The answer of course is immigration. From 2000 to 2007 employment amongst the UK-born grew at only 0.32 per cent per year slowing to 0.18 per cent afterwards. By contrast employment of the foreign-born grew at 6.67 per cent per year during the boom and at a still impressive 4.85 per cent per year in the subsequent period (Table 1). If we break down the foreign-born into those born in the EU27 and those born elsewhere we see that since 2007 there has been no slowdown in the growth of those born in the EU but a halving of the growth rate of those born outside the EU. Amongst the EU-born there has been a large change in composition: those born in the accession countries (the A10) now account for 58 per cent of the EU stock. But despite the rapid growth of migrants from the EU, migrants from the rest of the world still constitute 58 per cent of the foreign-born. In all, the foreign-born accounted for 17 per cent of UK employment in 2016, up from 8 per cent in 2000. And the foreign-born accounted for around three quarters (76.6 per cent) of the increase in employment in

Table 1: UK Employment by Country of Birth, Millions

				of which:	
	Total	UK-born	Foreign-born	EU27	non-EU
1997	26.523	24.547	1.975	0.651	1.324
1998	26.794	24.712	2.080	0.700	1.380
1999	27.167	25.050	2.116	0.697	1.419
2000	27.483	25.272	2.210	0.710	1.500
2001	27.711	25.397	2.311	0.725	1.586
2002	27.944	25.484	2.457	0.738	1.719
2003	28.223	25.656	2.565	0.752	1.813
2004	28.533	25.825	2.707	0.784	1.923
2005	28.853	25.940	2.911	0.884	2.027
2006	29.140	25.899	3.238	1.017	2.221
2007	29.379	25.846	3.525	1.174	2.351
2008	29.628	25.843	3.780	1.288	2.492
2009	29.154	25.358	3.788	1.288	2.501
2010	29.227	25.336	3.886	1.354	2.532
2011	29.375	25.218	4.147	1.498	2.649
2012	29.695	25.419	4.268	1.570	2.698
2013	30.042	25.591	4.437	1.652	2.785
2014	30.752	25.992	4.749	1.834	2.915
2015	31.281	26.214	5.050	2.061	2.989
2016	31.725	26.266	5.453	2.303	3.150
2017 (Jan-June)	31.931	26.267	5.660	2.366	3.294
Growth rates, % pa					
2000-2007	0.95	0.32	6.67	7.18	6.42
2007-2016	0.85	0.18	4.85	7.49	3.25

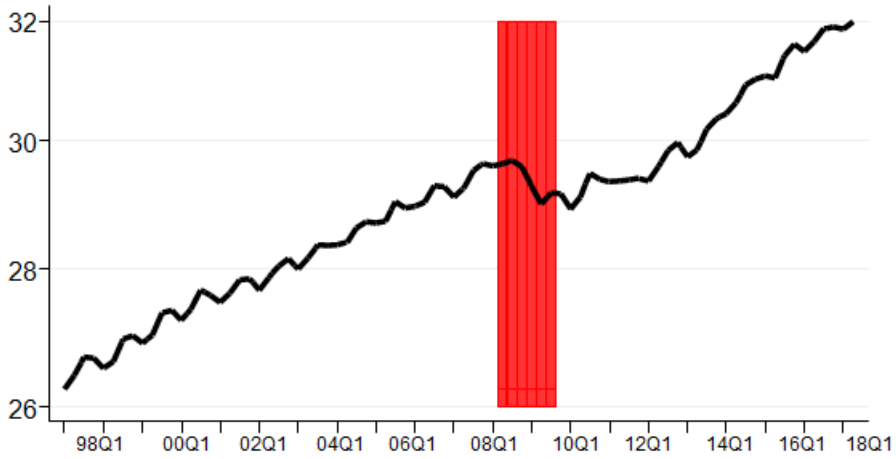
Source: ONS, "Employment by country of birth and nationality", August 2017 [emp06aug2017.xlsx]
Note: Annual averages of quarterly levels.

Chart 2: Unemployment Rate in the UK, 1997Q1-2017Q2 (per cent)



Note: Red bar marks Great Recession
Source: Office for National Statistics, "Labour Productivity: Apr to June 2017: Historical Estimates"[lprodhist.xlsx]

Chart 3: Employment in the UK, 1997Q1-2017Q2 (millions)



Note: Red bar marks Great Recession
Source: Office for National Statistics

the UK between 2000 and 2016, with this contribution split about equally between the EU27-born and the non-EU born (Table 1).[4]

Alongside employment, total hours worked also increased rapidly both before and after 2007. From 2000 to 2007 hours rose at 0.72 per cent per year and from 2007 to 2016 at 0.87 per cent per year. So not only did total hours rise more rapidly after the boom ended, but hours worked per worker also increased slightly.[5] In other words, it was not the case that the increase in employment was balanced by a fall in average hours worked by the typical worker.

International Comparisons

The Data

Most of the data used in this section come from the latest release of the EU KLEMS dataset (September 2017; available at www.euklems.net). These data go up to 2015 while in previous releases the data ended in 2007. For most countries the data go back to 1995 but most data are from 2000 as this was a cyclical peak in the United States (the end of the dot-com bubble) and a "growth pause" in other countries like the UK. The

4 These statistics are from the ONS, "Employment by country of birth and nationality", August 2017 (a spreadsheet entitled emp06aug2017.xlsx) and are for country of birth. The ONS also publishes a breakdown of employment by nationality which shows substantially lower figures for foreigners. But this is because many of the foreign-born become British citizens. For present purposes, country of birth is the relevant measure.

5 Office for National Statistics, Labour Force Survey, downloaded on 10/12/2107 from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/timeseries/ybus/lms. Variable cdid: YBUS.

great advantage of the EU KLEMS dataset is that labour productivity, hours worked, investment, capital services, human capital, and TFP are measured on a consistent basis across countries. In particular capital services (as well as capital stocks) are provided. Capital services is the appropriate measure for productivity analysis (OECD 2009) though unfortunately it is not a mandatory part of the System of National Accounts and so not provided routinely by national statistical agencies.[6]

A total of 29 countries are included in the latest release including (despite the name of the dataset) the US. In previous releases Australia, Canada and Japan were also included but are omitted from the September 2017 release. I have added Australia and Canada to the data used here since these have constructed their own productivity accounts using very similar principles to EU KLEMS.[7] However for these two countries the unit of analysis is the market or business sector while for the rest it is the whole economy. Japan is still omitted since recent productivity accounts for this country would not be found. I have also excluded six countries due to their very small size: Cyprus, Estonia, Latvia, Lithuania, Luxembourg and Malta. Most data are missing for Croatia.

In summary, for the countries included here, and for the whole period 2000-2015, twenty-four have data on GDP, 23 on labour productivity and hours worked, 15 have data on capital intensity and 14 on TFP.

Results

Table 2 shows the pattern of growth before and after the crisis. GDP growth declined in all 24 countries after 2007 by on average 2.69 percentage points. Greece, Finland, Italy, Portugal and Slovenia had negative growth in GDP post-crisis, i.e. in 2015 their level of GDP was still below the 2007 level. GDP growth in the UK was above the mean post-crisis: better than in France, and a bit less than in Germany and the United States.

Before the crisis, the growth of hours in the UK was below the cross-country mean though faster than

6 The EUKLEMS capital services measure is constructed out of asset stocks in the national accounts of the countries who provided these data. EU KLEMS constructs capital services as a rental-price-weighted aggregate over these stocks. As the website notes, there is a possible inconsistency here as each country uses its own assumptions about depreciation to estimate stocks while EU KLEMS uses a common set of depreciation rates (very similar to the rates used by the U.S. BEA) to estimate rental prices.

7 Data for Canada are from Statistics Canada, downloaded on 17/11/2017 from http://www.statcan.gc.ca/eng/start, a spreadsheet named cansim-3830021.xls. For Australia they are from Australian Bureau of Statistics, downloaded on 17/11/2017 from http://www.abs.gov.au/AusStats/ABS@.nsf/MF/5260.0.55.002, a spreadsheet named 52600550022016.xls.

in France, Germany, Italy and the United States. After the crisis hours declined in all countries except Denmark, Germany, Romania and Sweden. In the UK hours grew slightly faster after 2007 than before. Hours grew at a faster rate in the UK post-crisis than in any other country except Canada and Sweden.

Before the crisis labour productivity was growing more rapidly in the UK than in most of the advanced countries, faster than in Canada, France, Denmark, Germany, Ireland, Italy, the Netherlands and the United States, though slower than in Australia, Finland and Sweden. Some emerging markets like Bulgaria, Czech Republic, Romania, Slovakia, Slovenia and even Greece did better in 2000-2007 which likely reflects the realization of their catch-up potential. After the crisis labour productivity growth fell in 18 out of 22 countries, on average by 1.34 percentage points. In the UK growth was slower than in any other country except Finland and Greece where growth was negative. In these two countries GDP growth was also negative.

The growth of capital intensity fell in 9 out of 15 countries after the crisis. In the UK it grew at only 0.22 per cent pa after 2007. This compares with 1.04 per cent pa in Germany, 1.27 per cent in France and 0.96 per cent in the United States.

In summary, there is no striking difference between the UK and these other countries in GDP growth post-crisis. What is striking about the UK though is labour productivity growth (close to zero) and the growth of hours (comparatively rapid). The UK also saw the largest decline in the growth of capital intensity of any country in the dataset.

One other feature stands out in Table 2. After 2007 TFP growth fell in 12 out of 14 countries. In the UK the growth rate fell by 1.3 percentage points. The only exceptions to this pattern were Canada and Italy where TFP growth has been negative since 2000. TFP levels actually fell in 13 countries. In TFP the United States performed best after 2007 but even here the growth rate declined by 0.54 percentage points; the level of TFP in the United States was only a bit over 1 per cent higher in 2015 than it had been in 2007.

Can the Solow Model Explain the Puzzle?

Let us consider whether the textbook model of economic growth due to Solow (1956), still the workhorse model in many applications, can help to explain what has been happening in the UK in the boom, the Great Recession and the subsequent recovery. This section sets out the theory and

Table 2: Growth Rates of GDP, Hours, and Labour Productivity in 24 Countries, 2000-2007 and 2007-2015 (% per year)

		GDP (Y)		Hours (L)		Labour Productivity (y)	
Country	Code	2000-2007	2007-2015	2000-2007	2007-2015	2000-2007	2007-2015
Austria	AT	2.31	0.57	0.37	-0.12	1.94	0.7
Australia	AU	3.71	2.51	1.79	0.6	1.92	1.91
Belgium	BE	2.11	0.82	0.73	0.43	1.38	0.39
Bulgaria	BG	5.73	1.56	2.13	-1.06	3.61	2.62
Canada	CA	2.47	1.28	1.81	0.81	0.66	0.47
Czech Rep.	CZ	4.38	0.59	-0.19	0.01	4.58	0.61
Germany	DE	1.57	0.79	-0.13	0.31	1.70	0.48
Denmark	DK	1.31	0.37	0.47	-0.54	0.84	0.91
Greece	EL	3.74	-3.65	1.54	-2.67	2.20	-0.97
Spain	ES	3.37	-0.41	3.07	-1.79	0.30	1.38
Finland	FI	2.97	-0.84	0.82	-0.42	2.15	-0.42
France	FR	1.82	0.55	0.55	0.01	1.27	0.54
Hungary	HU	3.51	0.46	.	.	.	.
Ireland*	IE	4.72	0.04	2.83	-2.48	1.89	2.52
Italy	IT	1.13	-0.96	1.09	-1.08	0.04	0.12
Netherlands	NL	1.96	0.57	0.63	0.00	1.34	0.57
Poland**	PL	5.40	3.14	2.62	0.48	2.78	2.66
Portugal	PT	1.38	-0.49	-0.07	-1.47	1.45	0.98
Romania	RO	6.03	1.64	-1.81	-1.61	7.84	3.25
Sweden	SE	2.94	1.25	0.46	0.76	2.49	0.49
Slovenia	SI	4.43	-0.04	0.46	-0.20	3.97	0.16
Slovakia	SK	6.03	2.09	0.84	0.25	5.19	1.84
United Kingdom	UK	2.61	0.78	0.69	0.70	1.91	0.08
United States	US	2.08	0.85	0.37	0.23	1.70	0.63
Mean (unweighted)		3.14	0.56	0.83	-0.38	2.29	0.95
Min		1.13	-3.65	-1.81	-2.67	0.04	-0.97
Max		6.03	3.14	3.07	0.81	7.84	3.25

Source: For all countries except Canada and Australia: EU KLEMS, September 2017 release (www.euklems.net). Data for Canada are from Statistics Canada, downloaded on 17/11/2017 from http://www.statcan.gc.ca/eng/start, a spreadsheet named cansim-3830021.xls. Australian data are from Australian Bureau of Statistics, downloaded on 17/11/2017 from http://www.abs.gov.au/AusStats/ABS@.nsf/MF/5260.0.55.002, a spreadsheet named 52600550022016.xls.
Note: For Canada and Australia, figures are for the market sector. For all other countries, figures are for the whole economy.
∗ Ireland: 2007-2014, not 2007-2015, since Irish GDP in 2015 was distorted by tax manipulation by multinationals.
∗∗ Poland: 2003-2007, not 2000-2007, due to missing values in 2000, 2001 and 2002.

Table 3: Growth Rates of Capital Intensity, TFP, and Real Foreign Demand in 24 Countries, 2000-2007 and 2007-2015 (% per year)

		Capital intensity (k)		TFP (A)		Real Foreign Demand (Z)	
Country	Code	2000-2007	2007-2015	2000-2007	2007-2015	2000-2007	2007-2015
Austria	AT	2.12	1.54	0.89	-0.02	3.34	0.50
Australia	AU	3.55	3.76	0.21	-0.01	5.34	2.63
Belgium	BE	2.03	0.69	0.47	-0.1	2.63	0.44
Bulgaria	BG	.	.	.	.	3.92	-0.45
Canada	CA	2.12	1.46	-0.23	-0.13	2.17	0.17
Czech Rep.	CZ	4.10	4.32	2.20	-1.67	.	.
Germany	DE	2.45	1.04	0.87	-0.07	3.40	0.49
Denmark	DK	1.58	2.43	0.01	-0.39	2.86	0.53
Greece	EL	.	.	.	.	5.00	0.92
Spain	ES	1.44	2.91	-0.39	-0.44	2.37	0.27
Finland	FI	0.84	0.94	1.66	-0.94	3.35	0.40
France	FR	2.30	1.27	0.23	-0.35	2.94	0.29
Hungary	HU	.	.	.	.	3.83	0.38
Ireland*	IE	.	.	.	.	2.22	0.19
Italy	IT	1.46	1.66	-0.70	-0.51	3.28	0.43
Netherlands	NL	0.82	0.80	.	0.1	2.66	0.46
Poland**	PL	.	.	.	.	3.57	0.20
Portugal	PT	.	.	.	.	3.02	-0.29
Romania	RO	.	.	.	.	3.52	-0.03
Sweden	SE	2.85	1.80	-0.14	-0.73	3.22	0.36
Slovenia	SI	.	.	.	.	3.61	0.21
Slovakia	SK	.	3.36	.	0.07	3.79	0.40
United Kingdom	UK	1.86	0.22	1.01	-0.3	2.78	0.59
United States	US	2.30	0.96	0.69	0.15	3.08	1.25
Mean (unweighted)		2.12	1.82	0.48	-0.33	3.38	0.44
Min		0.82	0.22	-0.70	-1.67	2.17	-0.45
Max		4.10	4.32	2.20	0.15	5.47	2.63

Source: For all countries except Canada and Australia: EU KLEMS, September 2017 release (www.euklems.net). Data for Canada are from Statistics Canada, downloaded on 17/11/2017 from http://www.statcan.gc.ca/eng/start, a spreadsheet named cansim-3830021.xls. Australian data are from Australian Bureau of Statistics, downloaded on 17/11/2017 from http://www.abs.gov.au/AusStats/ABS@.nsf/MF/5260.0.55.002, a spreadsheet named 52600550022016.xls. Foreign demand: Export-Weighted Imports (EWI) from NIESR's NiGEM database.
Note: For Canada and Australia, figures are for the market sector. For all other countries, figures are for the whole economy. Real foreign demand (Z) for each country is measured by the export-weighted imports (EWI) of its trading partners in US dollars, deflated by the US GDP deflator (see text).
∗ Ireland: 2007-2014, not 2007-2015, since Irish GDP in 2015 was distorted by tax manipulation by multinationals.
∗∗ Poland: 2003-2007, not 2000-2007, due to missing values in 2000, 2001 and 2002.

then discusses its application to the UK.

Theory

The aggregate production function, assumed to be constant returns to scale and for simplicity to take the Cobb-Douglas form, is

$$Y = AK^{\alpha}L^{1-\alpha}$$

$$0 < \alpha < 1$$

or

$$y = Ak^{\alpha} \tag{1}$$

where $y := Y/L$ and $k := K/L$. Here Y is output (GDP), A is the level of TFP, L is labour (hours), assumed to be growing at the rate n, K is capital, y is output per unit of labour (productivity), k is the capital-labour ratio (capital intensity) and the parameter α can be identified with the share of capital; the symbol ":=" means "is defined to be". Capital accumulates in accordance with the following law:

$$\dot{K} = sY - \delta K \tag{2}$$

Here s $(= I/Y)$ is the investment ratio and δ is the depreciation rate, both assumed constant. Using (1) we can rewrite this as

$$\widehat{k} = sAk^{\alpha-1} - \delta - \widehat{L} \tag{3}$$

where a hat $(\wedge)$ denote a growth rate. e.g. $\widehat{y} = \dot{y}/y$. The growth rate labour of productivity is

$$\widehat{y} = \widehat{A} + \alpha\widehat{k} \tag{4}$$

Equations (3) and (4) constitute the short run dynamics of the model. We can use them to solve for the paths of y and k, given the initial level of k and the path of L.

As Solow showed, the model possesses a steady state where the long run growth rate of GDP is:

$$\widehat{Y}^{*} = \frac{\widehat{A}}{1-\alpha} + n \tag{5}$$

Here n is the growth rate of labour, assumed to be constant in the steady state, and a star $(*)$ denotes the steady state. The steady state growth rate of GDP per hour (productivity), denoted by g, which is also the steady state growth rate of capital intensity (k), is therefore

$$g := \widehat{y^{*}} = \widehat{k^{*}} = \frac{\widehat{A}}{1-\alpha} \tag{6}$$

Note that the growth rate of hours (n) has no effect on the long run growth rate of productivity or of capital intensity.

Application to the UK

Suppose now we consider an economy in a long run steady state as described by equation (6) which is now subject to a labour supply shock, an unexpected one-off rise in the labour supply with no change in any of

the parameters. This is a standard exercise in the manipulation of the Solow growth model where we seek to characterise the transition path from one equilibrium to another. The increase in the labour supply lowers the capital-labour ratio. So the marginal product of labour falls as does the real wage; the latter change is necessary to maintain full employment. The steady state growth rate and level of productivity are unchanged. So after the (instantaneous) fall in the capital-labour ratio the capital stock must grow more rapidly than before for a while, in order to restore the capital-labour ratio to its long run level; there is an incentive to do this because the marginal product of capital has risen. Labour productivity and the real wage must also grow more rapidly for a while. This process, an investment boom does not sound much like what has been happening in the UK since 2007. We therefore turn now to an alternative model of growth developed by Arthur Lewis.

The Lewis Model of Development in a Dual Economy

In 1954, Arthur Lewis published a seminal article on economic development in a dual economy (Lewis, 1954)[8]. His vision was based on the colonial economies of his own day in which a small modern, capitalist sector is embedded in a larger economy which uses pre-modern technology, the subsistence sector. The capitalist sector uses modern technology and has high average labour productivity while in the subsistence sector average productivity is low. The subsistence sector can be identified with agriculture though Lewis argued it could be extended to include petty traders and the servants of the well-to-do. He argued that in the subsistence sector the marginal product of labour is zero so there is surplus labour. People in the subsistence sector can be attracted to work in the capitalist sector by paying a wage which gives a (probably small) premium over the subsistence level of income; the latter is determined either by the average productivity of labour in the subsistence sector or by convention. This process can continue and the capitalist sector can expand till the surplus labour is exhausted.

We can formalize the Lewis model by assuming that in the capitalist sector a production function of the Solow type applies: see equation (1). Technical progress is assumed to be zero in the subsistence sector. The real wage (w) in the capitalist sector is a constant, determined by the subsistence

8 See Gollin (2014) for a modern assessment.

level of income plus some premium necessary to cover the costs of migration out of the subsistence sector. Capitalists set the real wage equal to the marginal product of labour:

$$w = (1-\alpha)AK^{\alpha}L^{-\alpha} = (1-\alpha)Ak^{\alpha} \tag{7}$$

Migration from the subsistence sector keeps the real wage constant:

$$\widehat{w} = \widehat{A} + \alpha\widehat{k} = 0 \tag{8}$$

which implies that

$$\widehat{k} = -\widehat{A}/\alpha \leq 0 \quad \text{if } \widehat{A} \geq 0 \tag{9}$$

(Lewis (1954) generally takes $\widehat{A} = 0$ though he certainly envisaged the possibility of technical progress). Consequently in the capitalist sector

$$\widehat{y} = \widehat{A} + \alpha\widehat{k} = \widehat{A} - \widehat{A} = 0 \tag{10}$$

i.e. labour productivity growth is zero: any technical progress is offset by falling capital intensity.

In the Lewis model, as long as unlimited supplies of labour last, growth in the capitalist sector is driven by demand for the products of this sector. Lewis is not very explicit about this, but one interpretation is that the capitalist sector is producing for export, e.g. the products of mines, plantations, or labour-intensive manufacturing, as in the export-processing zones later established by many developing countries, for which domestic demand is insignificant. So the model can be completed by adding an equation for demand and a market-clearing condition:

$$Y^d = g(Z) = \gamma Z^{\theta} \quad \gamma > 0, \theta > 0 \tag{11}$$

where Y^d is foreign demand for the country's exports and Z is world demand. I have picked a simple functional form which will be useful below. The market-clearing condition is

$$Y = Y^d \tag{12}$$

Then the long run growth rate of output in the capitalist sector, as long as labour supplies last, is given by $\theta\widehat{Z}$ and this equals the growth rate of the capitalist labour force:

$$\widehat{Y} = \widehat{A} + \alpha\widehat{k} + \widehat{L} = \widehat{L} = \theta\widehat{Z} \tag{13}$$

using (11).

The Lewis model, unlike the Solow model, does not make truly long run predictions about growth, since the surplus labour which drives the model will eventually be exhausted. After that point Lewis expected growth to be determined by what he called the "neo-classical" model, by which he likely meant something like the Solow

model though the latter was not to be published until two years after his own. If the Solow model applies after surplus labour is exhausted, then technical progress has to be the driver of growth in the long run.

If despite this caveat we compare the predictions of the two models we can note the following contrasts:

- In the Lewis model, growth is the opposite of "inclusive." Due to the expansion of the capitalist sector GDP and profits rise but the workers receive no benefit: their real wages are constant. In the Solow model, the rising tide lifts all boats.
- This difference in the conclusions is driven by the different assumptions about labour. In the Solow model, growth of the labour force is exogenous, in the Lewis model, it is endogenous (at least in the capitalist sector) and driven entirely by the demand of employers which in turn is driven by foreign demand.

The Neo-Lewis Model

How can the Lewis model, whatever its merits as a model of growth in a dual economy, have any application to a developed economy like the UK? The answer is that we can consider the whole UK economy like the capitalist sector of the Lewis model. The "subsistence" sector is now the rest of the world. The UK economy can draw on the rest of the world to augment its own home-grown labour.

The Lewis model, at least in my interpretation, has two essential elements. First, demand for exports is driven by demand in the rest of the world; second, labour input is endogenous and driven by the demands of employers. In what follows, which is called the neo-Lewis model, the first element is maintained but it is then necessary to explain how export demand determines demand for the remainder of UK output. The second element is dropped since it seems unrealistic to claim that labour input is determined entirely by employers. It is true that UK employers nowadays actively recruit overseas but immigration has its own dynamic, driven by conditions in the sending countries as well as differences in the receptivity of the possible destination countries (more on this below).

The Model

The economy produces a single good which can be consumed, invested or exported. A different consumer good can be imported. The size and growth rate of the labour force are exogenous. Goods and labour markets always clear (full employment). I make the small economy assumption that the terms of trade and foreign de-

mand for domestic output are exogenous.

Production, Investment and Capital

The production and capital accumulation side of the model are the same as in the Solow model; see equations (1)-(6). As before the domestic production function is:

$$Y = Ak^{\alpha}L \tag{14}$$

whence

$$\widehat{Y} = \widehat{A} + \alpha\widehat{k} + \widehat{L} \tag{15}$$

Investment and Capital Accumulation

I make the Solovian (and Keynesian) assumption that investment is proportional to output:

$$I = sY \quad 0 < s < 1 \tag{16}$$

From this and equations (2) and (14) we get the capital accumulation equation:

$$\widehat{k} = sAk^{\alpha-1} - \delta - \widehat{L} \tag{17}$$

This equation always holds but as shall be seen the assumption that s is a constant may have to be dropped.

Household demand

Let C be consumption, measured in units of domestic output, let D be consumers' expenditure on domestic output, let M be the quantity of imports purchased by consumers, and let p be the relative price of imports in terms of domestic output: $p := P_M/P$ where P is the domestic price and P_M the import price. Then

$$C = D + pM \tag{18}$$

The national income identity is:

$$\begin{aligned} GDP(E) &= C + I + X - pM \\ &= D + I + X = Y \\ &= GDP(O) \end{aligned} \tag{19}$$

and using (16)

$$D + X = (1 - s)Y \tag{20}$$

Consumers maximise utility U which depends on domestic goods and imports

$$\begin{gathered} U = D^{\omega}M^{1-\omega} \\ 0 < \omega < 1 \end{gathered} \tag{21}$$

subject to the budget constraint:

$$D + pM = C \tag{22}$$

The first order conditions of this problem yield

$$\frac{D}{M} = \frac{\omega}{1-\omega}p \tag{23}$$

Hence, differentiating with respect to time,

$$\widehat{D} = \widehat{M} + \widehat{p} \tag{24}$$

Balance of trade

The balance of trade, in units of domestic output, is $X - pM$. I assume that there is some mechanism, ultimately the intertemporal budget constraint, which prevents the balance moving from its equilibrium value given by:

$$X = \phi pM \qquad \phi > 0 \tag{25}$$

Some countries (e.g. Germany, the Netherlands) seem to be able to run a positive balance of trade indefinitely ($\phi > 1$) while others (e.g. the United States, Australia) have a negative balance for decades ($\phi < 1$). So no assumption as to the size of ϕ is made except that it is positive. The parameter ϕ presumably depends on demography and other factors such as preferences which are left in the background.

Differentiating (25) with respect to time,

$$\widehat{X} = \widehat{M} + \widehat{p} \tag{26}$$

From (24) and (26)

$$\widehat{D} = \widehat{X} \tag{27}$$

That is, domestic demand for domestic output grows in line with exports.

Foreign demand for exports

Foreign demand for exports is

$$X^d = \gamma Z^\theta \qquad \gamma > 0, \theta > 0 \tag{28}$$

Hence

$$\widehat{X}^D = \theta \widehat{Z} \tag{29}$$

Now we reach the key assumption. The supply of exports, X, cannot exceed demand but may not equal it either:

$$X \leq X^d \tag{30}$$

In good conditions the weak inequality (30) does not bind as an equality ($X < X^d$), in other words the home country can export as much as it likes. But after a sufficiently large shock to foreign demand the inequality may bind ($X = X^d$) — the country's exports are constrained by foreign demand.[9] So now we have two regimes to analyse, a good one and a bad one.

The two regimes

(a) good regime: $X < X^d$

Weak inequality (30) is not binding as an equality so the solution is the same as that of the Solow model: the short run dynamics are given by equations (15) and (17).

9 The idea that growth might be limited by foreign demand is also found in Kaldor (1966), Houthakker and Magee (1969) and Thirlwall (1979), though in the latter the idea is applied to developing countries

(b) bad regime: $X = X^d$

Equation (30) binds as an equality, so from (27) and (29)

$$\widehat{D} = \widehat{X} = \theta\widehat{Z} \tag{31}$$

Implicit in the bad regime is that the economy cannot grow as fast as in the good regime. In the good regime the economy is assumed to be in a steady state where

$$\widehat{I} = \widehat{K} = \widehat{Y} = g + n \tag{32}$$

Now in the bad regime by assumption we have

$$\theta\widehat{Z} < g + n \tag{33}$$

It is straightforward to show that this implies that in the bad regime

$$\widehat{Y} < g + n \tag{34}$$

Proposition:[10] Assume that in the good regime the economy was in a steady state in which output (Y), investment (I) and capital (K) were growing at the same rate, i.e. labour productivity (y) and capital intensity (k) were growing at rate g. Then in the bad regime, with a constant investment ratio, and given the same growth of labour supply in the two regimes, labour productivity and capital intensity grow more slowly than in the good regime. That is,

$$\widehat{Y} = \theta\widehat{Z} < g + n \tag{35}$$

and

$$\widehat{K} < g + n \tag{36}$$

Suppose that the investment ratio is lower in the bad regime than in the good one (which is what we find in the data). Then there must have been a period in which the investment ratio (I/Y) was falling, i.e. when I was growing less rapidly than Y. So at the onset of the bad regime investment and capital grow even less rapidly for a period while the bad regime "beds in."

In summary, in the bad regime foreign demand drives the growth of output. Investment and capital intensity then respond to ensure that the exogenously-given labour force is fully employed. So from (34) labour productivity growth in the bad regime is

$$\widehat{y} = \theta\widehat{Z} - \widehat{L} \tag{37}$$

Using (36) and solving for $\widehat{k}$ from (15):

$$\widehat{k} = \frac{1}{\alpha}[\theta\widehat{Z} - \widehat{A} - \widehat{L}] \tag{38}$$

So an increase in the growth rate of

10 For proof, see online appendix A (http://www.csls.ca/ipm/36/Oulton_appendix.pdf).

foreign demand raises the growth rate of capital intensity while an increase in the growth rate of labour supply lowers it, as does an increase in the TFP growth rate. The second and third of these predictions are exactly the opposite of the Solow model's: in the latter TFP growth and capital deepening are positively related and capital deepening is independent of labour supply growth, at least in the steady state.

Testing the Neo-Lewis Model

To test the neo-Lewis model empirically, equation (36) is assumed to apply in both periods, before and after the crisis, i.e. 2000-2007 and 2007-2015, denoted by superscript B and A respectively, but with a shift factor which is expected to be larger before the crisis. So for the i-th country

$$\begin{aligned} \widehat{y}_{\mathrm{i}}^{\mathrm{B}} &= \mu_{\mathrm{i}}^{\mathrm{B}} + \pi_Z \widehat{Z}_{\mathrm{i}}^{\mathrm{B}} + \pi_L \widehat{L}_{\mathrm{i}}^{\mathrm{B}} + \epsilon_{\mathrm{i}}^{\mathrm{B}} \\ \widehat{y}_{\mathrm{i}}^{\mathrm{A}} &= \mu_{\mathrm{i}}^{\mathrm{A}} + \pi_Z \widehat{Z}_{\mathrm{i}}^{\mathrm{A}} + \pi_L \widehat{L}_{\mathrm{i}}^{\mathrm{A}} + \epsilon_{\mathrm{i}}^{\mathrm{A}} \end{aligned} \tag{39}$$

Here $\epsilon_{\mathrm{i}}^{\mathrm{B}}$ and $\epsilon_{\mathrm{i}}^{\mathrm{A}}$ are error terms and we expect $\mu_{\mathrm{i}}^{\mathrm{B}} > \mu_{\mathrm{i}}^{\mathrm{A}}$,$\pi_Z > 0$, and $\pi_L < 0$. Then taking differences (growth after minus growth before) we obtain the equation to be used for testing the hypothesis:

$$\begin{aligned} \Delta\widehat{y}_i = (\mu_{\mathrm{i}}^{\mathrm{A}} - \mu_{\mathrm{i}}^{\mathrm{B}}) \\ +\pi_z \Delta\widehat{Z}_i + \pi_L \Delta\widehat{L}_i + (\epsilon_{\mathrm{i}}^{\mathrm{A}} - \epsilon_{\mathrm{i}}^{\mathrm{B}}) \end{aligned} \tag{40}$$

An analogous equation for testing predictions about capital intensity can be based on equation (37).

Now we need an empirical proxy for world demand, Z. This is measured for each country by the export-weighted imports (EWI) of its trading partners, which indicates the potential for a country to expand its exports. For the i-th country the EWI is defined as

$$EWI_i = \frac{\sum_j X_{ij} M_j}{\sum_j X_{ij}} \tag{41}$$

where the X_{ij} are country i's exports to country j and M_j is total imports of country j. So if country i tends to export to countries whose imports are growing rapidly then EWI_i will be growing more rapidly than if its exports are concentrated on slow-growing countries. (This will be the case even if the country's exports to rapidly growing economies are for some reason not growing as fast as those countries' total imports). This variable is initially nominal and measured in US dollars.[11] It is converted to real values with the US GDP deflator. The growth rate of real EWI before and after the crisis appears in

11 This variable is part of the database of the National Institute Global Econometric Model (NiGEM). I am grateful to Garry Young and Yanitsa Kazalova for making it available to me.

Table 4: Tests of the Neo-Lewis Model: Dependent Variables are the Change in the Growth of Labour Productivity ($\Delta\hat{y}$) and the Change in the Growth of Capital Intensity ($\Delta\hat{k}$)

	change in labour productivity growth (Δy)				change in capital intensity growth (Δk)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\widehat{k}$		1.146**	1.270***	0.868*		-0.05032	-0.398	-0.402
		(0.474)	(0.395)	(0.471)		(0.669)	(0.255)	(0.276)
$\Delta\widehat{L}$	-0.369*		-0.433***	-0.507***	-0.586***		-0.606***	-0.618***
	(0.2)		(0.135)	(0.146)	(0.0834)		(0.0766)	(0.0903)
$\widehat{Y}^B$				.0.343*				-0.075
				(0.168)				(0.27)
Constant	-1.745***	1.995	1.751	1.602	-0.983***	-0.577	-1.985**	-1.833
	(0.377)	(1.231)	(1.024)	(1.15)	(0.167)	(1.782)	(0.737)	(1.088)
Observations	22	22	22	22	14	14	14	14
R-squared	0.168	0.285	0.513	0.603	0.686	0	0.713	0.716

Source: Data from Table 2.
Note: *** p<0.01, ** p<0.05, * p<0.1. OLS estimates; robust standard errors in parentheses.

Table 2. There has been a substantial decline in all countries. The cross-country average is a fall of 2.85 percentage points, with a considerable range around this average (standard deviation: 0.69).

The results of estimating equation (39) are in Table 4. Consider first column (3) where the change in labour productivity growth is the left-hand-side variable. Both the independent variables, export demand and hours, are highly significant (at the 1 per cent level) and have the correct sign.[12] Given that this is a difference between two cross sections, the level of explanatory power is quite high (R-squared = 0.513). However the neo-Lewis model predicts that the coefficient on hours should be -1 while the estimated coefficient is smaller in absolute value, -0.433. The upper panel of Chart 4 shows the added variable plots for this regression from which it is clear that no single country is driving the results. The specification in column (3) in effect assumes that the same constant applies to all countries which could lead to biased estimates.

One way to deal with this is fixed effects but there are not enough observations for this. So instead the growth rate of GDP over 2000-2007 ($\widehat{Y}^B$) is added in column (4) to proxy for country-specific effects. The coefficient on this variable is negative and significant at the 10 per cent level, indicating that countries which did well before the crisis did worse after it. The coefficient on export demand is now smaller and less significant but hours remains highly signifi-

12 The coefficient on the growth of foreign demand ($\Delta\widehat{Z}$) might be thought quite large, even when the growth of GDP in 2000-2007 is included. (as in column 4). But note that this coefficient measures not the short run effect on aggregate demand when exports rise but the long run effect on GDP of a rise in foreign demand, the parameter θ. There is a multiplier effect here since in the model's bad regime domestic demand is determined by foreign demand: See equation (25).

cant and somewhat larger in absolute value. The lower panel of Chart 4 shows the added variable plots for this regression. Even more than the upper panel, this shows that the results are not being distorted by outliers.

Columns (5)-(8) in Table 4 have the same specification as columns (1)-(4) except that the dependent variable is now the change in the growth rate of capital intensity. The hours variable is highly significant again but export demand is not. However there are only 14 countries now.

So the facts are broadly consistent with the neo-Lewis model put forward here, although the model has not captured all the important features of the data since the coefficient on hours is not equal to minus one. Even setting this aside, there is of course no guarantee that the model is true: any set of facts is consistent with an unlimited number of theories. The problem is that the sort of facts discussed here will only be observed on very rare occasions, most recently the Great Recession. The only previous event in the twentieth century comparable to this in scale was the Great Depression of the 1930s. Hence it is difficult for conventional econometric techniques to achieve empirically rigorous results.

Is It All About TFP?

Did the TFP slowdown precede the Great Recession?

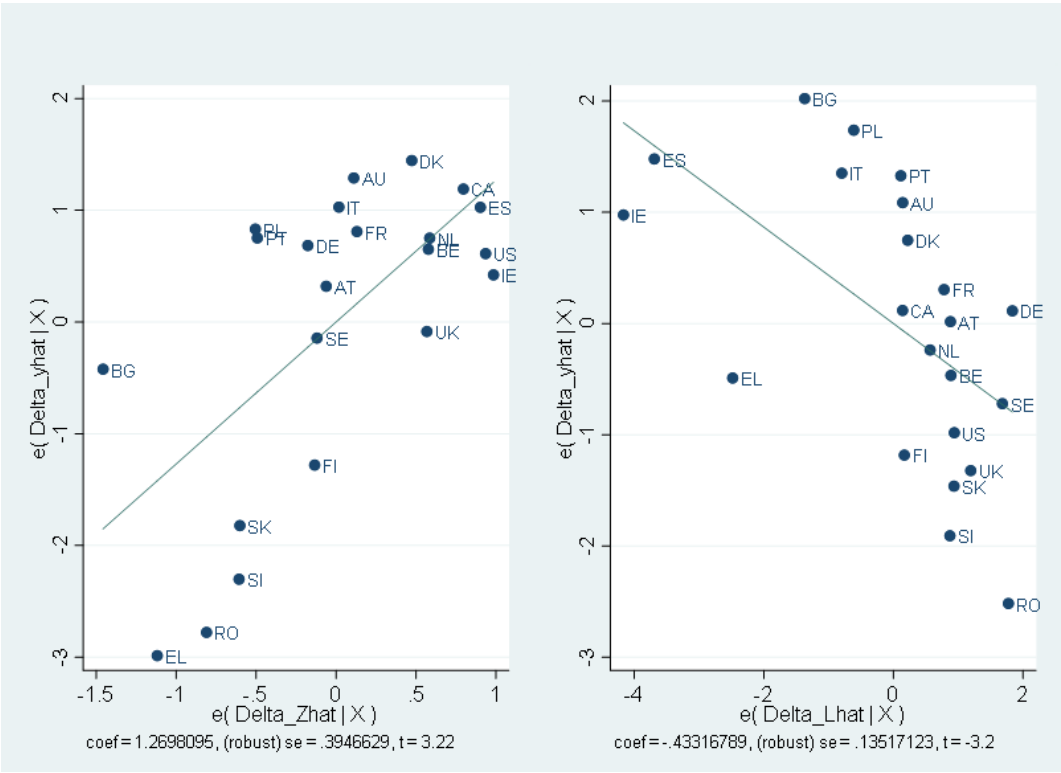
TFP growth has fallen dramatically since the crisis as we have seen (Table 2). In the UK's case, the slowdown in TFP accounts for 71 per cent of the slowdown in labour productivity growth, in a growth accounting sense (Table 2). And this finding survives untouched when a longer list of intangible assets is included under capital (Goodrich *et al.*, 2018). So is not the TFP slowdown the main story, eclipsing the role of any slowdown in the growth of capital intensity? Furthermore, it is often asserted that the slowdown in TFP growth preceded the financial crisis, suggesting that a micro-based explanation should be sought and implying that the policy remedy is "structural reforms" (Andrews *et al.*, 2015; Bergaud *et al.*, 2014; Fernald, 2015; Cette *et al.*, 2016).[13]

However, if one just considers the period up till 2007, it is very difficult to find evidence of a TFP slowdown in most countries. Chart 5, re-

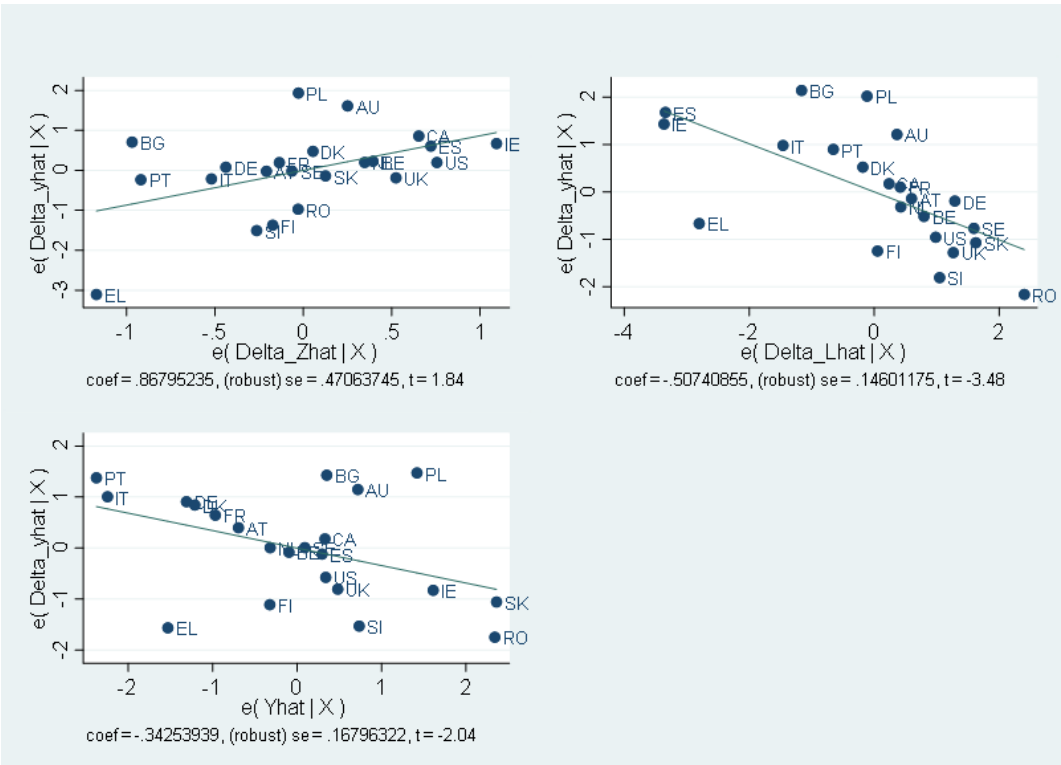
13 Micro studies have thrown light on the evolution of productivity. For example, using French firm-level data Cette et al. (2018) exhibit a number of adverse trends which could impact TFP growth. But the timing is problematic for explaining the post-2007 collapse. For example, they find that the speed of convergence of laggard firms to leading firms actually rose in the period 2007-2012, though it fell sharply in 2014 (their latest year).

Chart 4: Added Variable Plots (Dependent Variable: Change in Growth of Labour Productivity)

(a) For Column (3) of Table 4



(b) For Column (4) of Table 4



See Table 2 for country codes.

Chart 5: TFP Growth in the Market Sector in 18 Countries to 2007

Source: Oulton (2016b), derived using EU KLEMS (the March 2011 update of the November 2009 release).

produced from Oulton (2016b), shows TFP growth in the market sector in 18 countries; data are from the earlier release of the EUKLEMS database which fortuitously stops in 2007.[14] Two simple measures of the trend are shown: the mean over the data period for each country (dashed line) and a Hodrick-Prescott (HP) trend (red line). In most cases the country's actual TFP growth rate is at or near its mean level at the end of the period; exceptions are Australia and Ireland. In addition, in most cases the HP trend is flat or rising in the years leading up to the financial crisis. This suggests that the collapse exhibited since 2007 must be somehow related to the crisis and the subsequent Great Recession and not to pre-existing adverse micro factors.[15]

The United States is often regarded as the technology leader and therefore its TFP record is particularly signifi-

14 This is the March 2011 update of the November 2009 release which includes more countries. Also the capital services measure is better since unlike in the 2011 release asset stocks are estimated using a common set of geometric depreciation rates.

15 An alternative possibility is that capital services growth after 2007 has been overstated and so TFP growth has been understated as a result of the recession. See online appendix B for discussion of this (available at: http://www.csls.ca/ipm/36/Oulton_appendix.pdf).

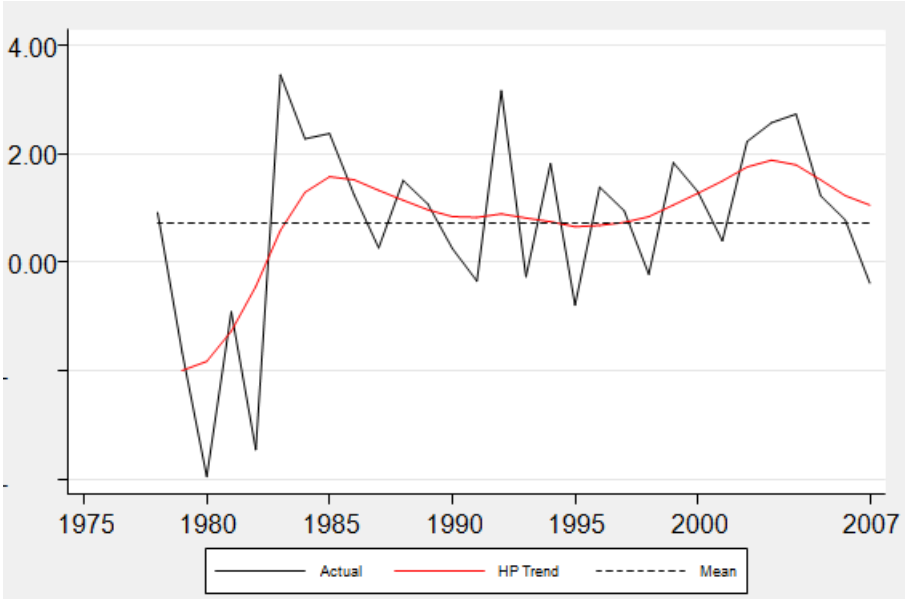
cant, so Chart 6 focuses on the US experience up to 2007. The HP trend confirms the earlier finding of Fernald (2015) that growth slowed after 2004. But it did not slow by all that much and was still 1.05 per cent per year in 2007, substantially above the trend rate in most of the 1980s and 1990s and also above the mean rate over 1978-2007.

Further evidence comes from comparing trend TFP growth as measured by the HP trend at the end of the boom in 2007 with the actual TFP growth after the boom, i.e. 2007-2015: see Table 5. (The HP trends are for the market sector so the actual growth rates after the boom are also for the market sector where possible.) The trend growth rate tells us what we would have predicted TFP growth to be in the years after 2007, if we had data only up to the end of the boom, i.e. if we place no reliance on hindsight. We see that there is a very substantial difference between the predicted and the actual rates: the outcome was below the predicted rate in every case except Australia and on average in these countries by 1.77 percentage points per year. This evidence goes against the view that the zero or negative TFP growth rates seen after the crisis are just a continuation of a pre-existing slowdown.

A more sophisticated analysis is available for the United States. Crafts and Mills (2017) estimate trend TFP growth in the United States, in the 1967-2016 period. They apply a time series model to Fernald's quarterly series for TFP growth in the business sector (Fernald, 2014). TFP growth is modelled as a random walk (the trend) plus a zero-mean, auto correlated "noise" process. Using Fernald's series for the whole period 1947-2015, Crafts and Mills (2007: Figure 3) find that the trend has been slowing continuously since 1967, from around 1.5 per cent per year in that year to around 1.0 per cent per year in 2016. The actual outturn according to Fernald's data over 2007-2015 was 0.56 per cent per year (0.63 per cent per year adjusted for utilisation). In other words the outturn was substantially lower than the trend as estimated by Crafts and Mills. Another way to look at it is to note that in 2016 the Crafts-Mills trend growth rate was about 0.1 per cent per year lower than in 2000, so the slowdown in trend growth is quite modest in relation to what actually occurred, about 0.6 per cent.[16] So the slump in US TFP growth since

16 From the spreadsheet accompanying Fernald (2014), dated 1 February 2018, it can be calculated that comparing 2007-2015 with 2000-2007, unadjusted TFP in the US business sector growth slowed down by 0.63 percentage points per year; adjusted for utilisation the slowdown was 0.57 percentage points per year. This is very similar to the slowdown of 0.54 percentage points per year in Table 1 which is for the whole economy.

Chart 6: Market Sector Total Factor Productivity Growth in the United States, 1978-2007 (per cent per year)



Source: EU KLEMS (March 2011).
Note: Trend growth rate is that of HP-smoothed TFP level. Dashed lines denotes mean of actual TFP growth

2007 is not correctly described as a decline in the trend rate. It was also not foreseeable using just the data up to 2007 since Crafts and Mills (2007: Figures 3 and 4) find a rising trend if only the 25 years of data up to 2007 are used.[17]

An alternative explanation: the externality hypothesis

On the face of it, and in the light of the rise of the digital economy, it seems very implausible that a fortuitous and exogenous decline in the rate of innovation could account for slow productivity growth after 2007 in any of the countries studied here. The alternative explanation is that the recession itself has somehow adversely affected TFP growth. Two channels suggest themselves.

First, the amount of innovation taking place in the economy may be temporarily reduced, due to a loss of business confidence (Oulton and Sebastiá-Barriel, 2017). Innovation is implemented through or accompanied by investment in intangibles (e.g.

17 Antolin-Diaz *et al.* (2017) argue that most of the slowdown in US GDP occurred prior to the Great Recession. But Figure A.1 in their online appendix which uses the latest vintage of GDP data for their whole sample shows that their estimate of long run GDP growth fell sharply after 2007. They do not show rolling estimates which would enable one to see what their model would predict just using data up to 2007.

Table 5: Trend TFP Growth Rate at the End of the Boom Versus Performance After the Boom (Market Sector[a], 14 Countries, % p.a.)

Country	HP trend growth rate at the end of the boom (2007)	Mean actual TFP growth rate after the boom(2007-2015)	Difference (actual minus trend)
Australia	-1.27	-0.01	1.26
Austria	2.31	-0.17	-2.48
Belgium	0.76	0.17	-0.59
Czech Republic	4.14	-1.67	-5.81
Denmark	0.39	-0.25	-0.64
Spain	-0.28	-0.43	-0.15
Finland	3.32	-0.73	-4.05
France	0.93	-0.69	-1.62
Germany	1.51	-0.14	-1.65
Italy	-0.01	-0.51	-0.5
Netherlands	2.19	-0.09	-2.28
Sweden	2.05	-0.73	-2.78
United Kingdom	2.09	-0.41	-2.5
United States	1.05	0.08	-0.97
Average (unweighted)	1.37	-0.40	-1.77

Source: HP trend growth rates calculated from EU KLEMS (www.euklems.net, March 2011 update of November 2009 release): see Oulton (2016b). Mean actual TFP growth rates after 2007 from September 2017 releases of EU KLEMS.
Note: End of the boom is 2007 for all countries except Belgium for which it is 2006. All countries included for which TFP is available in both the March 2011 and September 2017 releases of EU KLEMS.
a. Czech Republic, Italy and Sweden after the boom: whole economy since market sector not available.

R&D, in-firm training, or expenditure of management time on corporate restructuring) or it could take the form of new entrants into an industry bringing new products, new technology or new business methods. All this is (arguably) what lies behind TFP growth as conventionally measured.

Now innovation is a cumulative process and the supply of workers and entrepreneurs capable of innovating is likely to be inelastic. So unlike with physical capital a reduction in innovation in one period cannot easily be made up in a subsequent one: in other words, less innovation today means that the future level of TFP is permanently lower. A reduction in the TFP level will also lead to a secondary effect, a reduction in the desired level of capital, again reducing labour productivity.

In short, more rapidly expanding output might raise animal spirits leading to a greater willingness to experiment with new business methods. Intangible investment seems to be particularly likely to generate externalities but is also riskier and so may have been particularly likely to be cut during the recession (Corrado *et al.*, 2017).

A second channel posits a positive connection between the growth of output and the growth of TFP. The starting point here is Fabricant's Law. In panel data on US manufacturing industries over the period 1899-1939 Fabricant (1942) observed a positive correlation between the growth of output and the growth of labour productivity.[18] In earlier work we observed the same pattern for 124 UK manufacturing industries over 9 subperiods within the overall span 1954-1986 (Oulton and O'Mahony, 1994). We also observed a positive correlation between output growth and TFP growth.

But which way does the causation run, from output to TFP or the reverse? The usual argument is that this correlation is uninteresting. TFP growth happens to be higher in some industries which initially leads to higher profits. This attracts entry leading to higher output which the market absorbs by lower prices. So causation runs from TFP growth to output growth via lower relative prices. We found however that the correlation between output growth and relative price growth was much weaker than that between output growth and TFP growth, which casts doubt on this explanation (Oulton and O'Mahony (1994), chapter 7).[19]

The alternative explanation for the positive correlation between TFP growth and output growth is that some form of increasing returns is involved. Hall (1988) and Bartelsman *et al.* (1994) found support for increasing returns in US data, and Caballero and Lyons (1990) in European data. Oulton (1996) found support on the same UK manufacturing data just described (in the latter the externality seemed to be at the manufacturing sector level rather than the industry level). Hall (1988) had invoked a "thick market externality" to explain the phenomenon: an example is the delivery van which travels as many miles on average in good

18 Fabricant's Law is also known as Verdoorn's Law (Verdoorn 1980). There is a parallel literature testing Verdoorn's Law and drawing inspiration from among others Kaldor (1966) who stressed the role of demand in promoting output and productivity growth in a virtuous circle; see e.g. Magacho and McCombie (2017).

19 There is also some evidence for a negative relationship between TFP growth and the growth of labour input over long periods, e.g. 1970-2007 (De Michelis*et al.*, 2013).

times as bad but delivers more packages when times are good.

This suggests the effect operates at business cycle frequencies and is due to varying utilisation, hence the term "short run increasing returns". But this is not the only possibility. Oulton (1996) found that the externalities seem to apply peak-to-peak as well as over the course of the business cycle, which is not consistent with the thick market story. A second possible type of externality is a learning effect: knowledge of new techniques and methods diffuses faster through the economy, the faster the rate of overall expansion. This type of effect would be expected to operate peak-to-peak.

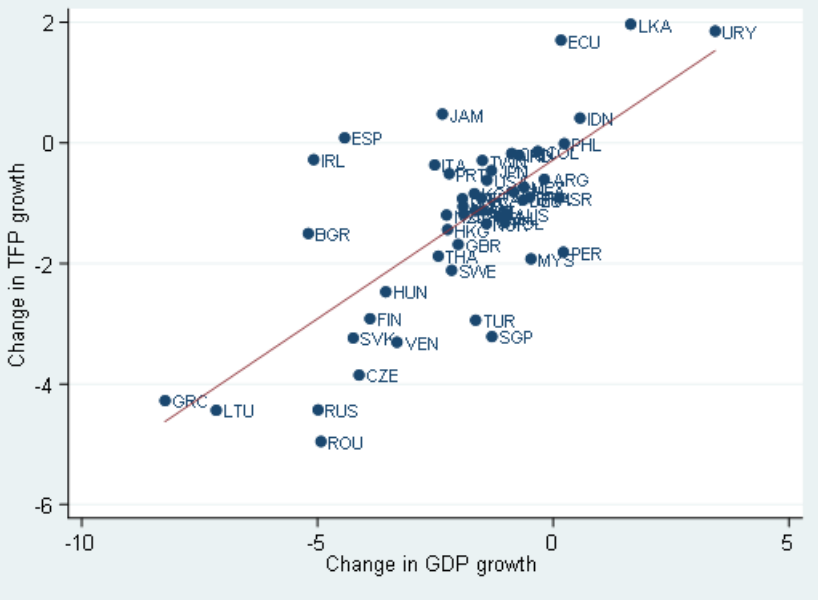
It is difficult to test these ideas using only macro data and particularly using the latest release of the EU KLEMS dataset since this dataset has TFP data for only 14 countries. So consequently, the latest release (version 9.0) of the Penn World Table, described in Feenstra *et al.* (2015) is used.[20] After eliminating countries with populations of less than 2 million and countries with no data on hours worked there remain 52 countries for which TFP is available. I use the PWT's "national accounts" variables for indices of real GDP, real capital stock and TFP; total hours worked is calculated as average hours per worker times the number of workers.[21] On average in these 52 countries TFP growth slowed down by 1.29 percentage points per year, GDP by 1.92 percentage points per year, capital by 0.26 percentage points per year, and hours by 1.00 percentage points per year.

The externality hypothesis suggests that, on cross-country data, the bigger the slowdown in GDP, the bigger the slowdown in TFP. Table 6 shows how the change in the TFP growth rate between the periods 2007-2014 and 2000-2007 relates to the change in the growth rate of GDP, the change in the growth rate of capital, and the change in the growth of hours between the same two period (columns 1-3). Much the strongest relationship is with GDP and it is positive: the bigger the slowdown in GDP, the bigger the slowdown in TFP (Chart 7). The coefficient on GDP is highly significant (t = 6.6). Taken literally, this says that a slowdown of one percentage point in GDP growth causes a slowdown of 0.53 percentage points in TFP growth. The coefficients on the other variables, capital and labour,

20 Freely downloadable from https://www.rug.nl/ggdc/productivity/pwt.

21 Two drawbacks of the Penn World Table should be noted. First, the capital variable is the aggregate capital stock, not the superior capital services measure. Second, the terminal year is 2014, not 2015.

Chart 7: Change in TFP Growth Versus Change in GDP Growth (52 countries)



Source: Penn World Table, version 9.0. Average annual growth rates over 2007-2014 minus annual average growth rates over 2000-2007.

are not significant. The pattern of the correlations is interesting. Each is between TFP and a component of TFP so it might be objected that any relationship is just mechanical. But why then is it much stronger with GDP than with capital or labour?

Column 4 of Table 6 is a test of the Solow model's predictions about the effect of a slowdown in TFP growth which that model takes to be exogenous. The Solow model predicts that a slowdown in TFP growth will cause a slowdown in the growth rate of capital intensity. But the coefficient on the latter, 0.28, is much smaller than the model predicts: with a capital share of about one third the coefficient should be about 1.5 (see equation (6)). It is also insignificant.

These correlations do not of course prove that a GDP slowdown causes a TFP slowdown. But they are certainly consistent with the industry-based studies cited above. They are also consistent with the neo-Lewis model which sees the GDP slowdown as caused by constrained demand for exports. The model now works through the TFP channel as well as the capital-deepening one to explain the labour productivity slowdown.[22]

Conclusion

22 For further discussion and extensions of the neo-Lewis model and of the externality hypothesis, see online appendix B. For discussion of the policy implications if the present approach is accepted, see online appendix C (available at: http://www.csls.ca/ipm/36/Oulton_appendix.pdf).

Table 6: Testing the Externality Hypothesis in 52 Countries

	Dependent Variable			
	Change in TFP growth			Change in K/L growth
Independent Variables	(1)	(2)	(3)	(4)
Change in GDP growth	0.527***			
	(0.0803)			
Change in capital growth		0.135		
		(0.151)		
Change in hours growth			-0.118	
			(0.152)	
Change in TFP growth				0.283
				(0.194)
Constant	-0.281	-1.259***	-1.412***	1.105***
	(0.168)	(0.221)	(0.218)	(0.363)
N	52	52	52	52
R-squared	0.514	0.018	0.018	0.058

Note: Changes are measured as annual average growth over 2007-2014 minus annual average growth over 2000-2007. OLS estimates; robust standard errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1.
Source: Penn World Table, version 9.0, and own calculations.

Rapid rates of immigration in conjunction with low rates of growth of export demand in the aftermath of the Great Recession can explain the UK productivity puzzle. Labour market flexibility can explain why we have also had low unemployment and high employment growth. The reason why the UK was not able to have fast labour productivity growth after the crisis even though immigration rates were similar to those of the pre-crisis period is that after the crisis the growth of foreign demand for UK exports fell. This has led to low rates of capital accumulation and consequently low rates of labour productivity growth. This has been compounded by virtually zero growth rates of TFP, but this last is a factor common to virtually all the countries studied here; indeed in some countries like Sweden the level of TFP has fallen substantially.

Due to the nature of their labour markets and social policies, most EU countries have had much less rapid growth rates of labour after the crisis. Consequently, they have had better labour productivity growth but worse labour market outcomes than the UK.

The factors leading to people from all over the world coming to the UK to work are of course complex. Much must depends on conditions of the immigrants' countries of origin. But by the nature of its flexible labour market and other institutions, the UK has been much more welcoming to migrants as workers than have most other EU countries.

That the facts are consistent with this explanation has been demonstrated by a simple modification of the workhorse Solow growth model. Taking inspiration from the early work of Arthur Lewis the Solow model has been adapted to make the growth of demand for a country's exports depend on the growth of foreign de-

mand. In normal times this constraint does not bind. In abnormal times, like the Great Recession and its aftermath, foreign demand acts as a constraint on the home economy. If labour supply is rising sufficiently rapidly in this situation due to immigration while output is constrained by foreign demand, then capital intensity will rise less rapidly or even fall, leading to stagnant or falling labour productivity, a situation which might be described as "growth with unlimited supplies of labour." Output in other countries is also constrained by foreign demand but their inflexible labour markets plus their adherence to the European Social Model mean that the effects show up as higher unemployment and lower job creation, accompanied by lower immigration.[23]

Slow growth of capital intensity is not however the whole story. The UK and the other countries studied here have seen a large fall in TFP growth as well. It is argued that this is a consequence of slow growth in GDP since 2007, in turn due to constrained demand for exports as emphasised by the neo-Lewis model. The countries with the largest falls in GDP growth also had the largest falls in TFP growth. Based on earlier industry-based studies, I argue that this relationship is causal, due to a form of increasing returns but working here in reverse, so that slow growth of GDP leads to slow growth of TFP.

References

Aghion, Philippe, Tim Besley, John Browne, Francesco Caselli, Richard Lambert, Rachel Lomax, Nick Stern and John Van Reenen (2013) "Investing for Prosperity: Skills, Infrastructure and Innovation," in Tim Besley and John Van Reenen (eds.) *Investing for Prosperity*, pp. 1-50. London: LSE Academic Publishing.

Andrews, Dan, Chiara Criscuolo and Peter N. Gal (2015) "Frontier Firms, Technology Diffusion, and Public Policy: Micro Evidence from OECD Countries," OECD Productivity Working Papers, No. 02, Paris: OECD Publishing.

Antolin-Diaz, J., Drechsel, T. and Petrella, L. (2017) "Tracking the Slowdown in Long-Run GDP Growth," *Review of Economics and Statistics*, Vol. 99, pp. 343-356.

Bartelsman, Eric J., Ricardo J. Caballero and Richard K. Lyons (1994) "Customer- and Supplier-Driven Externalities," *American Economic Review*, Vol. 84, No. 4 September, pp. 1075-1084.

Bergeaud, Antonin, Gilbert Cette and Rémy Lecat (2014) "Productivity Trends from 1890 to 2012 in Advanced Countries," Banque de France, Document de Travail No 475.

Caballero, R. J. and R. K. Lyons (1990) "Internal Versus External Economies in European Industry," *European Economic Review*, Vol. 34, pp. 805-830.

Cette, Gilbert, John G. Fernald and Benoit Mojon (2016) "The Pre-Great Recession Slowdown in Productivity," *European Economic Review*, April, pp. 3-20.

Cette, Gilbert, Simon Corde and Remy Lecat (2018) "Firm-Level Productivity Dispersion and Convergence," *Economics Letters*, forthcoming.

23 see online appendix B for more on this (available at: http://www.csls.ca/ipm/36/Oulton_appendix.pdf).

Corrado, Carol, Jonathan Haskel and Cecilia Jona-Lasinio (2017) "Knowledge Spillovers, ICT and Productivity Growth," *Oxford Bulletin of Economic and Statistics*, Vol. 79, No. 4, pp. 592-618.

Crafts, Nicholas and Terence C. Mills (2017) "Predicting Medium-Term TFP Growth in the United States: Econometrics vs. 'Techno-Optimism'," *National Institute Economic Review*, No. 242, November, pp. R60-R67.

De Michelis, Andrea, Marcello Estevão and Beth Anne Wilson (2013) "Productivity or Employment: Is it a Choice?," *International Productivity Monitor*, Vol. 25, No. 4 (Spring), pp. 41-60. http://www.csls.ca/ipm/25/IPM-25-Michelis-Estevao-Wilson.pdf

Fabricant, Solomon (1942) "Employment in Manufacturing, 1899-1939: An Analysis of its Relation to the Volume of Production," New York: National Bureau of Economic Research.

Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015) "The Next Generation of the Penn World Table," *American Economic Review*, Vol. 105, No. 10, pp. 3150-3182.

Fernald, John G. (2014) "A Quarterly, Utilization-Adjusted Series on Total Factor Productivity," FRBSF Working Paper 2012-19 (updated March 2014).

Fernald, John G. (2015) "Productivity and Potential Output Before, During and After the Great Recession," in Jonathan A. Parker and Michael Woodford (eds.) *NBER Macroeconomics Annual* 2014, Vol. 29, University of Chicago Press.

Gollin, Douglas (2014) "The Lewis model: a 60-Year Retrospective," *Journal of Economic Perspectives*, Vol. 28, No. 3, pp.71-88.

Goodridge, P., J. Haskel and G. Wallis (2018) "Accounting for the UK Productivity Puzzle: a Decomposition and Predictions," *Economica*, Vol. 85, July, No. 339, pp. 581-605.

Haldane, Andrew G. (2017) "Productivity Puzzles," https://www.bankofengland.co.uk/speech/2017/productivity-puzzles.

Hall, Robert E. (1988) "The Relation Between Price and Marginal Cost in US Industry," *Journal of Political Economy*, Vol. 96, pp. 921-947.

Houthakker, H.S. and Stephen P. Magee (1969) "Income and Price Elasticities in World Trade," *Review of Economic and Statistics*, Vol. LI(2), pp. 111-125.

Kaldor, Nicholas (1966) *Causes of the Slow Rate of Economic Growth in the United Kingdom*, Cambridge, UK: Cambridge University Press.

Lewis, W. Arthur (1954) "Economic Development with Unlimited Supplies of Labour," *The Manchester School*, Vol. 22, No. 2, pp. 139-191.

Magacho, Guilherme R. and John S. L. McCombie (2017) "Verdoorn's Law and Productivity Dynamics: an Empirical Investigation Into the Demand and Supply Approaches," *Journal of Post Keynesian Economics*, Vol. 40, No. 2, pp. 600-621.

Martin, Bill (2018) "The UK Productivity Puzzle: Does Arthur Lewis Hold the Key? by Nicholas Oulton. Comment," Working Paper No. WP, Centre for Business Research, Judge Business School, University of Cambridge.

OECD (2009) *Measuring Capital: OECD Manual 2009: 2nd Edition*, OECD, Paris.

OECD (2016) "The Economic Consequences of Brexit: a Taxing Decision," Economic Policy Paper no. 16, April.

Office for Budget Responsibility (2017) *Economic and Fiscal Outlook*, November.

Oulton, Nicholas (1996) "Increasing Returns and Externalities in UK Manufacturing: Myth or Reality?" *Journal of Industrial Economics*, Vol. 44, No. 1 March, pp. 99-113.

Oulton, Nicholas (2016a) "Prospects for UK Growth in the Aftermath of the Financial Crisis," in Jagjit Chadha, Alec Chrystal, Joseph Pearlman, Peter Smith, and Stephen Wright (eds.) *The UK Economy in the Long Expansion and its Aftermath*, Cambridge: Cambridge University Press.

Oulton, Nicholas (2016b) "The Mystery of TFP," *International Productivity Monitor*, No. 31, Fall, pp. 68-87.

Oulton, Nicholas and Mary O'Mahony (1994) *Productivity and Growth: A Study of British Industry, 1954-1986*, Cambridge: Cambridge University Press.

Oulton, Nicholas and Maria Sebastiá-Barriel (2017) "Effects of Financial Crises on Productivity, Capital and Employment," *Review of Income and Wealth*, Series 63, Supplement 1, February, S90-S112, 2017.

Solow, Robert M. (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, Vol. 70, No. 1, pp. 65-94.

Tenreyro, Silvana (2018) "The Fall in Productivity Growth: Causes and Implications," Speech, www.bankofengland.co.uk/speeches.

Thirlwall, A.P. (1979) "The Balance of Payments Constraint as an Explanation of International Growth Rate Differences," *Banca Nazionale del Lavoro Quarterly Review*, Vol. 32, No. 128, March, pp. 45-53.

Verdoorn, P.J. (1980) "Verdoorn's Law in Retrospect: A Comment," *Economic Journal*, Vol. 90, June, pp. 382-385.