The Market for South Wales Coal 1874-1913

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Explaining industrial growth remains as much the desideratum of economic historians today as it was when so labelled by Fogel and Engerman some twenty years ago.[1] In remedying this deficiency the sticking point for most industries has been separating the distinctive effects of demand and supply on output and price. The nineteenth-century British coal industry has proven no exception. Indeed regional variety and the lack of a standard product accentuate the difficulties, and led Church, after a wide-ranging discussion of the market for coal, to resist defining precisely the respective roles of demand and supply.[2] More specifically, Mitchell identified the absence of an estimate for coal's price elasticity of demand as the major obstacle to formal analysis of the coal industry's development.[3] This article attempts to model explicitly the market for coal by establishing the elasticities of the demand and supply curves, and measuring the extent to which the demand and supply curves shifted in the years 1874-1913. To lessen the difficulties arising from a lack of homogeneity within British coalmining it focuses on south Wales, the location of the largest British coalfield by 1913.[4] The estimates for the elasticities of and shifts in the demand and supply curves provide a basis for explaining movement in the output and price of south Wales coal in the period 1874-1913.

The south Wales coal industry grew relatively quickly in the decades before the First World War, with its share of British coal output rising from 12 per cent in the 1870s to 20 per cent by 1913. On the demand side the main impetus behind comparatively fast growth were exports, especially to France and Italy, and the expansion of steam shipping, which replaced the iron industry as the chief outlets for Welsh coal. Forty per cent of British coal ex-

[1] Fogel and Engerman, 'A model'.
[2] Church, *British coal*, p. 60.
[3] Mitchell, *Economic development*, p. 34.
[4] Walters, *South Wales coal*, provides, along with Church, *British coal*, and Mitchell, *Economic development*, the most useful sources for information on south Wales coalmining in the years 1874-1913.

ports originated from south Wales by 1913, which meant Welsh coal was contributing almost five per cent to overall British exports. Meeting these demands required the deployment of substantial resources. South Wales provided employment for almost one quarter of Britain's one million coal miners by 1913. A corollary to labour force expansion was a rapid growth of the capital stock, estimated at four per cent per annum for the period 1872-1913.[5] Resource expansion was accompanied, from the 1880s, by falling productivity. Output per man year in the south Wales' coalfield was 22 percent below its 1883 peak by 1913.[6]

Rather curiously the onset of productivity decline in the 1880s coincided with improved financial fortunes for the south Wales coal industry. After the collapse of the 1873 boom an upward trend in prosperity was not re-established until the late 1880s. While output growth was slower after the 1880s, (see figure 1) the upturn in the relative price of coal accelerated growth in the real value of south Wales production. Hence the financial fortunes of the south Wales coalfield between 1874-1913 divide neatly at the late 1880s. In the earlier years the benefits of rising productivity and faster output growth were constrained by falling coal prices. From the late 1880s higher prices improved the south Wales coalfield's prosperity. The major purpose of this article lies in explaining the demand and supply influences which shaped these price, and coal output trends, and caused the turnaround in the south Wales coalfield's financial fortunes in the late 1880s. Since improved prosperity was accompanied by falling productivity, the consequences for the coal owners, miners, and the British economy more generally of lower productivity are considered. To pre-empt, it does seem that much of the south Wales industry's improved fortunes after the 1880s stemmed from the somewhat perverse effects of productivity decline.

I

Explaining the development of the south Wales coal industry in the years 1874-1913 largely involves articulating the influences operating within competitive markets since transport improvements and regional competition had effectively undermined the possibility of cartelization before 1874. Hence demand and supply influences on the industry's development may be represented by,

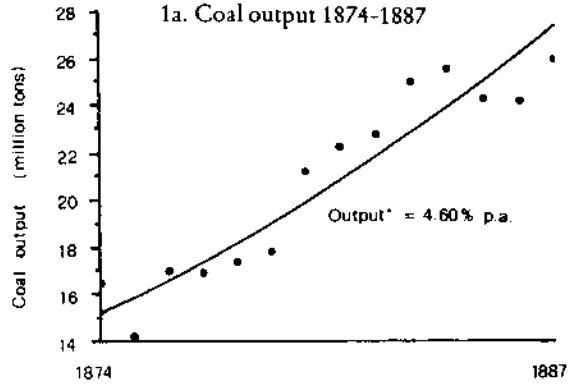
$$Q = DP^{-a} \quad (1)$$

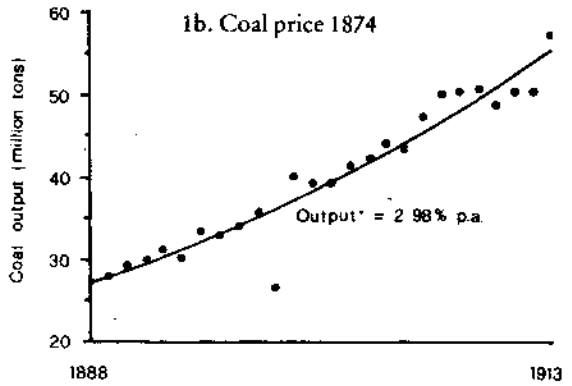
$$Q = SP^{b} \quad (2)$$

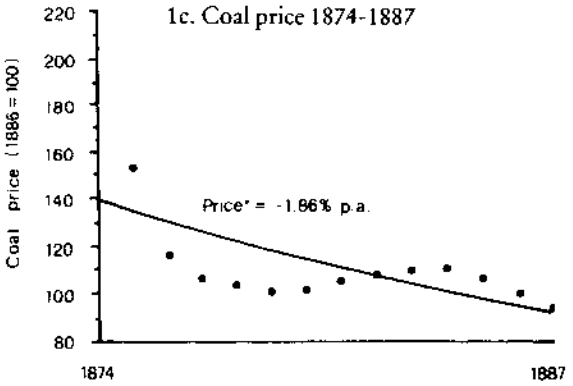
[5] Mitchell, *Economic development*, p. 50.

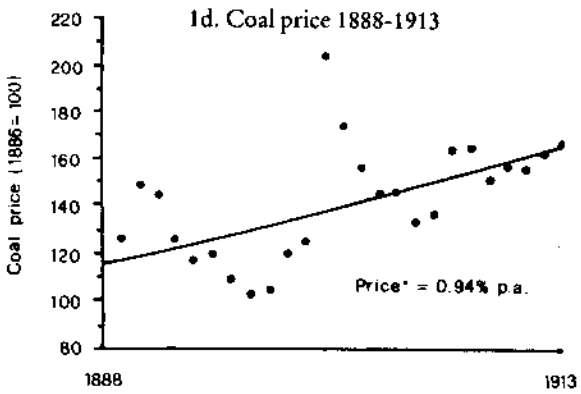
[6] Walters, 'Labour productivity', p. 300. Part of the decline resulted, as Church emphasises, from shorter hours. Using output per man year to measure productivity reflects the concern here with explaining annual movements in coal output and price.

Figure 1
SOUTH WALES COALMINING 1874-1913
(* = growth rate)









where Q represents output, P price, D and S demand and supply curve shift variables, and a and b the price elasticities of demand and supply.[7] Solving for P and Q, and taking rate of growth analogues yields,

$$Q^* = b/(b+a)D^* + a/(b+a)S^* \quad (3)$$

and

$$P^* = 1/(b+a)D^* - 1/(b+a)S^* \quad (4)$$

where * denotes the percentage rate of growth. Movement in coal output and price are thus seen to depend both on influences which shift the demand and supply curves, and on the price elasticities of demand and supply. Practical use of equations 3 and 4 firstly requires elaboration of the variables which shifted the demand and supply curves for Welsh coal.

Establishing the demand shift influences is comparatively straight forward. Four considerations dominated the demand for south Wales coal before 1914. These were the adoption of steam-based technology in continental Europe, the growth of steam shipping, the fortunes of the south Wales pig iron industry, and the price of substitutes for Welsh coal. Exports replaced the iron industry as the main outlet for Welsh coal after 1870. By 1913 over half south Wales coal was exported, primarily to France and Mediterranean Europe. Demand from steam shipping also grew rapidly, and accounted for 10 per cent of south Wales coal sales by 1913. There was limited use of alternative fuels before 1913 which meant coal from other fields, especially north-east England, was the main substitute for Welsh coal. Together these considerations suggest demand shift influences for south Wales coal may be represented by,

$$D = zF^gB^hI^iN^j \quad (5)$$

where F represents overseas demand, B steam shipping, I the Welsh iron industry, N the price of north east coal, z is a constant, and g, h, i, and j the respective demand elasticities.

Specifying the influences which shifted the supply curve for south Wales coal presents a more complex task. Firstly the technical relationship between coal output and the factors of production used to make that output needs to described. Defining the south Wales coal industry's production function as,

$$Q = AL^cM^dK^e \quad (6)$$

where A denotes total factor productivity, L labour, M materials, K capital stock, and c, d, and e the respective output elasticities, enables the short-run (in which the capital stock is fixed) profit maximising supply function to be written as,

$$Q = [A^{1/e}W^{-c/e}R^{-d/e}K]P^{(c+d)/e} \quad (7)$$

where W and R represent wages and the price of materials. The terms in the

[7] FOGEL and ENGERMAN, 'Introduction', elaborates on this framework.

rectangular brackets are equivalent to S, the supply curve shift variable in equation 2, and (c+d)/e denotes the price elasticity of supply. Hence supply curve shifts depend on changing productivity, factor prices, and the capital stock, along with the relevant output elasticities. The price elasticity of the short-run supply curve is also determined by the output elasticities from the production function.

There are two possible strategies for measuring shifts in the supply curve for south Wales coal. Explicit measurement of the individual supply shift variables in equation 7 offers the obvious route. Separate measurement of the individual supply shift variables would allow the distinctive contributions of productivity, capital stock growth, and changing factor prices, on coal output and price to be established. However, since the available estimates of productivity and the capital stock are not ideal, using these indicators might lead to the overall role of supply in the coal market being misrepresented. An attempt to unpin the individual influences which shifted the supply curve for south Wales coal follows in section III below. For the moment the simpler, and probably more robust strategy of summarising overall shifts in supply is adopted.

Rearranging equation 2 to $S = Q/P^b$ shows that shifts in the supply curve can be measured with output and price data if the price elasticity of supply can be ascertained.[8] How big an impact price changes had on coal supply depended on the technical conditions of coal production. These are defined by equation 6, the production function. The output elasticities from the production function indicate that the price elasticity of supply b, equals (c+d)/e, the ratio of the variable to fixed factors output elasticities. Clearly the smaller the role played by capital, the fixed factor of production in the short run, the greater the short-run price elasticity of supply. Intuitively it can be suggested that the relative labour intensity of the pre-1914 south Wales coal industry implies an elastic short-run supply curve. The actual magnitude of the elasticity can, on certain assumptions, be measured by data on factor shares, and this approach is followed below.[9] The resulting estimate for the elasticity of supply, in conjunction with coal output and price data, allows overall shifts in the supply curve to be measured.

II

The theoretical framework for analysing the market for south Wales coal has been established. Put simply, movement in the price and output of south

[8] Joskow and McKelvey, 'Fogel-Engerman model' and Dick, 'Canadian newsprint' provide discussion of the procedures.

[9] The assumptions are competitive markets and constant returns to scale. Neither seems unreasonable for south Wales' coalmining in the years 1874-1913 given the quantity and size distribution of pits. See Supple, *British coal*, p. 303.

Wales coal in the years 1874-1913 depended on influences which shifted the demand and supply curves, and the price elasticities of these curves. The practical problems of measurement now need to be confronted. Once the price elasticity of the supply curve has been ascertained, the demand elasticities can be estimated. Solving equations 1 and 2 for P and Q, substituting the demand shift influences specified by equation 5, and taking logarithms yields,

$$\log P = 1/(b+a)[\log z+g\log F+h\log B+i\log I+j\log N-\log S] \quad (8)$$

and

$$\log Q = b/(b+a)[\log z+g\log F+h\log B+i\log I+j\log N]+a/(b+a)\log S \quad (9)$$

Estimating the parameters in either of these equations, given prior information for b, the price elasticity of supply, allows the price and other elasticities of demand to be measured. The elasticities in conjunction with indicators for the shifts in the demand and supply curves, enables the separate contribution of demand and supply to movement of south Wales coal output and price (see equations 3 and 4) to be established.

Measuring the variables in equations 8 or 9 does not raise major difficulties. The passing of the Coal Mines Regulation Act in 1872 led Divisional Mines Inspectors to report coal output figures for subsequent years.[10] Price is measured by export values at south Wales ports, since pithead values were not collected systematically until 1882.[11] These output and price data, together with estimates for factor shares, are also used to indicate overall supply curve shifts. The investigations of the Sankey Commission ascertained capital's share, including royalties, to be 19 per cent of coal output's value for the years 1889-1913, which implies a price elasticity of supply of 4.25.[12] Data for capital's share is not available for earlier years, but Mitchell estimated labour's share from a limited sample of collieries at 60-9 per cent for the period 1873-89, a range not markedly out of line with Sankey's 62.5 per cent estimate for labour's share in the years 1889-1913.[13] Assuming material's share also remained roughly stable, it seems reasonable to treat the price elasticity of supply as constant throughout the period 1874-1913. Hence shifts in the supply curve, logS in equations 8 and 9, can be measured by logQ-4.25logP.

[10] WALTERS, 'Labour productivity', p. 300 reports these data.

[11] See MITCHELL, *Economic development*, p. 273. Coal price data throughout are defalted by Feinstein's GDP deflator. See FEINSTEIN, *National Income*, p. T132.

[12] *R.C. on coal*, (P.P. 1919, XIII), p. 7. Although the precision of the factor shares data, and hence the estimate for the price elasticity of supply might be questioned since the figures strictly pertain to the British coalfield generally, it seems undeniable that the short-run supply curve for south Wales coal was highly price elastic. Even if capital's share had been as high as 20%, the price elasticity would still be 4.

[13] MITCHELL, *Economic development*, p. 287. Mitchell does argue that labour's share rose modestly in the years to 1913.

Turning to the demand side, exports of south Wales coal were overwhelmingly directed towards France and the Mediterranean region. Together France and Italy took over 60 per cent of Welsh coal exports throughout the period 1874-1913. The demands derived from Italian industrialization were the more dynamic, with Italy taking 32 per cent of Welsh coal exports in the early twentieth century. Railways were a major reason for French and Italian coal imports, with both of these countries' state railways using Welsh coal almost without exception. Other continental uses for Welsh coal are difficult to establish precisely, but since railway development tended to mirror coal-based industrial growth in continental Europe, the volume of French and Italian railway traffic should provide a satisfactory indicator of the export demand for Welsh coal.[14] For the other demand shift variables, Britain's dominance of steam shipping before 1914, suggests tonnage of steamers registerd in the United Kingdom should indicate the demand for coal from steam shipping.[15] Output of the south Wales pig iron industry can be used to represent the demand for Welsh coal from the local iron industry.[16] Coal prices at north-east England ports are used to measure the price of the main substitute for south Wales coal.[17]

Estimating equation 8 by ordinary least squares yields the following result,

$$\begin{array}{lccccccc} \log P & = & 0.776 & + 0.034\log F & + 0.129\log B & + 0.078\log I & + 0.057\log N & - 0.224\log S \\ & & (1.20) & (2.54) & (14.12) & (7.29) & (2.30) & (-35.18) \end{array}$$

$R^2 = 0.99$, D.W. = 2.31, and the figures in brackets are 't' values. Demand elasticities implied by this equation, and estimates for the parameters in equations 3 and 4 are reported in table 1.

Table 1
ELASTICITIES OF DEMAND AND SUPPLY

$a = 0.209$	$b = 4.25$	$1/(b+a) = 0.224$
$a/(b+a) = 0.047$	$b/(b+a) = 0.953$	$g = 0.152$
$h = 0.575$	$i = 0.348$	$j = 0.254$

[14] MITCHELL, *European statistics*, pp. 592-3 provides data for tonnes/kilometres carried by French and Italian railways. Missing Italian data for the years 1900-4 is interpolated. In years prior to 1885 the distances tonnes of freight were carried is not known for Italy. These are estimated by back projecting 1885-99 trends.

[15] MITCHELL and DEANE, *British statistics*, pp. 218-9.

[16] MITCHELL and DEANE, *British statistics*, p. 132.

[17] MITCHELL, *Economic development*, p. 273.

Table 2
GROWTH OF DEMAND AND SUPPLY CURVE SHIFT VARIABLES % p.a.

	1874-1887	1888-1913		1874-1887	1888-1913
F	2.69	3.86	gF	0.41	0.59
B	7.23	3.83	hB	4.16	2.20
I	1.53	0.38	iI	0.53	0.13
N	−3.09	0.41	jN	−0.78	0.10
			Demand	4.32	3.02
			Supply	13.27	−1.12

In contrast to the elastic short-run supply curve, the demand for south Wales coal, according to this estimate, had a low price elasticity of −0.209. This price elasticity, together with the other demand elasticities, and estimates for the growth of the demand and supply curve shift variables, allow movement of south Wales coal output and price to be explained. Table 2 presents estimates of growth rates for the demand and supply shift variables. These data, estimated by least squares trends, have been constructed for the years 1874-87 and 1888-1913 to permit examination of the south Wales coalfield's changing fortunes.

The south Wales coal industry experienced more dramatic changes on the supply side than in demand within the years 1874-1913. Overall demand growth was respectable throughout the period 1874-1913, although the rate fell from over four per cent per annum between 1874-1887, to around three per cent per annum in the years 1888-1913. The demand growth slowdown resulted largely from retardation in steam shipping and the south Wales iron industry not being fully countered by faster export growth and higher coal prices in north-east England. Shifts on the supply side were more striking, with rapid growth of 13.27 per cent per annum in the period 1874-1887, and subsequent decline to 1913. An attempt to assess the relative force of the individual elements which determined supply curve shifts is made in section III. For the moment it is worth noting (see equation 7) that productivity movements had a major impact on supply since these are weighted by the reciprocal of the low elasticity of output with respect to capital. Thus shifts in productivity had a much stronger impact than equivalent growth in the capital stock on supply. Falling productivity, rising factor prices, and slower capital stock growth are all relevant to explaining the negative supply-curve shifts from the late 1880s, and are more fully explored below. The immediate concern is to examine how demand and supply shaped the market for south Wales coal.

The separate contributions of demand and supply to movement in the output and price of south Wales coal are summarised in table 3 for both the periods 1874-87 and 1888-1913. The differing fortunes of the south Wales coal industry in the two periods can now be readily explained.

Table 3

THE MARKET FOR SOUTH WALES COAL % p.a.

	1874-1887	1888-1913
$Q^* = b/(b+a)D^* + a/(b+a)S^*$	$4.12 + 0.62 = 4.74$	$2.88 - 0.05 = 2.83$
$P^* = 1/(b+a)D^* - 1/(b+a)S^*$	$0.97 - 2.97 = -2.00$	$0.68 + 0.25 = 0.93$
actual output*	$= 4.60$	$= 2.98$
actual price*	$= -1.86$	$= 0.94$

The real value of south Wales coal output grew 3.92 per cent per annum in the years 1888-1913, well above the 2.74 per cent per annum achieved between 1874-87, since rising prices more than offset retardation in the volume of production. Improved financial fortunes after the 1880s resulted from a number of characteristics and changes in the coal market. Since the price elasticity of coal demand, at −0.209, remained low in the years to 1913, shifts in supply were felt primarily through price. Rapid supply-side growth in the period 1874-87 only raised coal output by 0.62 per cent per annum, but reduced price by almost three per cent per annum. Hence supply-side expansion before 1888 would have reduced the real value of coal output had its effects not been offset by demand growth. The elasticity of the short-run supply curve for coal meant the effects of demand-curve shifts chiefly impinged on output. Demand growth by itself was sufficient to raise coal output by over four per cent per annum between 1874-87, and also ameliorated the pace of price decline. In effect demand growth was responsible for 85 per cent of the growth of south Wales coal output in the years 1874-87 and, given the buoyant supply conditions, maintained an upward trend in the real value of coal output.

The financial fortunes of the south Wales coalfield improved markedly in the quarter century before the First World War. Faster growth in the real value of output, approaching four per cent per annum in the years 1888-1913, resulted largely from changes on the supply side. Negative shifts in supply, given the price inelasticity of coal demand, would by itself, only have reduced output modestly in the period 1888-1913. The major effect of the adverse supply changes was to raise the price of coal. Slower demand growth after 1887 did reduce the pressure on coal prices, but the negative supply shift

was sufficiently strong to reverse the sharp deflation in coal prices apparent since 1874. It was the upturn in prices that was responsible for improving the financial fortunes of the south Wales coal industry after the 1880s. Output growth was slower in these years primarily because of less buoyant demand conditions, although weak supply also played a small role. On balance however adverse supply conditions raised prices by more than output growth was reduced. The outcome, somewhat paradoxically, was that supply-side weaknesses improved the prosperity of the south Wales coal industry in the decades immediately prior to the First World War.

III

The basis of the pre-1914 supply-side weaknesses in south Wales coalmining, given their importance in shaping the fortunes of the industry, deserves fuller exploration. Elaboration of the individual elements which contributed to overall shifts in supply requires the decomposition of the short-run supply curve. Though these components can only be tentatively measured, this is worth doing to shed some light on the reasons for the supply shifts, and also to provide a check on the robustness of the summary indicator used thus far to measure overall shifts in the supply curve. To reiterate shifts in the short-run supply curve (see equation 7) may be denoted by,

$$S^* = (5.26)A^* - (3.29)W^* - (0.97)R^* + K^* \qquad (10)$$

where * represents the percentage rate of growth, and the terms in brackets are output elasticities estimated by factor shares.[18] Clearly, because of coalmining's low capital intensity, shifts in productivity had a relatively great impact on supply. There seems little doubt that rising productivity to the 1880s and the subsequent fall played a major role in shaping movement in the supply curve, but its precise role is difficult to establish in the absence of reliable total factor productivity estimates. Output per man year in south Wales coalmining grew 2.31 per cent per annum in the years 1874-87, and fell 0.63 per cent per annum in the period 1888-1913. How closely these labour productivity trends matched total factor productivity depends on the magnitude of shifts in the ratio of labour to other factors of production.

The best that can be done is to establish plausible boundaries for movement in total factor productivity. In the period 1874-87 labour productivity growth will overstate that of total factor productivity since the capital-labour ratio was rising, perhaps by as much as three per cent per annum.[19] With

[18] Labour's, material's and capital's shares are taken as 0.625, 0.185, and, 0.19. See *R.C. on coal*, (P.P. 1919, XIII), p. 7.

[19] Capital stock growth has been estimated by MITCHELL, *Economic Development*, p. 50, at 5.31 per cent per annum between the years 1872 and 1889. Reliable

capital's share at 19 per cent, this suggest total factor productivity grew at 1.74 per cent per annum. This figure probably represents a lower bound for productivity growth since it assumes land resources expanded at a rate equivalent to that of the reproducible capital stock. There was plenty of scope in the 1880s to expand the natural resource base of the south Wales coal industry - the number of pits in operation grew 70 per cent in the twenty years after 1888, but the pace of land expansion may not have matched that of the reproducible capital stock. Hence the labour productivity growth rate of 2.31 per cent per annum represents an upper bound and 1.74 per cent per annum a lower bound of total factor productivity growth in the years 1874-87, with the lower figure perhaps being closer to the actual rate.

Estimating total factor productivity boundaries for the period 1888-1913 presents a more complex task since account needs to be taken of resource depletion. There seems little doubt that labour productivity growth will understate that of total factor productivity after the 1880s since the ratios of both reproducible capital and land to labour were probably falling, and hence −0.63 per cent per annum can be considered a lower bound for total factor productivity growth. The decline in capital per worker has been estimated, on the same basis as for the earlier period, at −0.35 per cent per annum for the years 1888-1913, which, with capital's share at 0.19, indicates −0.56 per cent per annum total factor productivity growth. This figure probably still overstates productivity decline since the land-labour ratio may have fell faster than the reproducible capital-labour ratio. Crudely approximating land expansion by the number of pits in south Wales, which grew 1.4 per cent per annum in the years 1888-1913, suggests the land-labour ratio was declining by −2.2 per cent per annum.[20] Apportioning capital's share at 0.13 for reproducible capital and 0.06 for land, yields an upper bound (since land expansion may have exceeded pit growth as mine size increased) of −0.50 per cent for total factor productivity growth.[21] The boundaries that have been established, 1.74 to 2.31 and −0.63 to −0.50 per cent per annum respectively for total factor productivity growth in the periods 1874-87 and 1888-1913 are crude, but indicate the possible contributions made by productivity to supply side shifts.

labour force data are not extant before 1874, (see WALTERS, 'Labour productivity'). Trends in coal output suggest the labour force was around eight per cent below 1874 levels in 1872. The implied labour force growth rate of 2.31 per cent per annum for the period 1872-89, indicates the capital-labour ratio was growing at three per cent per annum. It should be noted that these growth rates, unlike the others in this paper, have been calculated between end points. The ensuing total factor productivity calculations treat expansion of material use and the labour force as equivalent.

[20] See WALTERS, *South Wales coal*, p. 358 for numbers of pits.

[21] The factor proportions are based on the findings of the *R.C. on coal*, (P.P. 1919, XIII), p. 7.

Assigning values to the variables in the short-run supply curve, equation 10, yields the following results,[22]

	5.26A*	−3.29W*	−0.97R*	+K*	=	S*
1874-1887						
upper bound	12.15	−0.13	−0.04	+5.31	=	17.29
lower bound	9.15	−0.13	−0.04	+5.31	=	14.29
1888-1913						
upper bound	−2.63	−1.97	−0.45	+3.26	=	−1.79
lower bound	−3.31	−1.97	−0.45	+3.26	=	−2.47

For the years 1874-87 the results indicate a range between 14.29 and 17.29 per cent per annum for supply-side shifts. Since actual productivity growth was probably closer to the bottom estimate, these findings conform reasonably well with the summary indicator, which put overall supply curve shifts at 13.27 per cent per annum.[23] It seems that productivity growth was, at a minimum, responsible for 64 per cent of supply-side expansion in the period 1874-87, and capital stock expansion for the remainder since factor prices had little effect in these years. For the period 1888-1913 the estimates for supply curve shifts range from −1.79 to −2.47 per cent per annum. The upper bound is closer to the summary supply shift estimate of −1.12 per cent per annum, and should represent a better approximation of supply-side growth since it embodies a productivity estimate which makes allowance for increasing labour intensity in south Wales coalmining after the 1880s. Falling productivity is sufficient by itself to explain the negative shifts in supply between 1888 and 1913, but rising factor prices also had a strong negative influence. To some extent continuing capital stock growth ameliorated the depressing influences of falling productivity and rising factor prices on supply in the quarter century before 1914.

Decomposing, albeit rather crudely, the individual elements on the supply side provides clear insights into the causes of the south Wales coal industry's changing prosperity, and the role played by productivity in shaping the coal-

[22] Materials comprise a wide range of commodities including, timber, iron, ropes, lamps, fodder, and gunpowder. Prices of individual materials generally moved in unison. Since there was also parallelism between wage and material costs, wages are used to proxy material costs. See MITCHELL, *Economic development*, pp. 282-91.

[23] An alternative strategy is to use the indicator for overall supply shifts in conjunction with factor price and capital stock data to infer total factor productivity growth. This suggests total factor productivity growth of 1.55 and −0.37 per cent per annum respectively for the periods 1874-87 and 1888-1913. Since the available capital stock data only pertains to reproducible assets this route is not followed. Nevertheless the implied productivity growth amount to 62 and 175 percent respectively of supply shifts in the years 1874-87 and 1888-1913, and would not change the spirit of the following discussion.

field's fortunes. Using the lower productivity bound for the years 1874-87 and the upper for the period 1888-1913, since these are the more plausible and will also tend to understate the importance of productivity, allows changes in supply to be written as,

$$\begin{array}{rcrrrr} \Delta S & = & 1/e\Delta A & -c/e\Delta W & -d/e\Delta R & +\Delta K \\ -16.08 & = & -11.78 & -1.84 & -0.41 & -2.05 \end{array}$$

where Δ represents the difference in growth rates between 1888-1913 and 1874-87. The productivity turnaround was responsible for 73 percent of the difference in supply-side growth between the two periods. Slower growth of the capital stock and rising factor prices account in roughly equal proportions for the remainder of the downward shift in supply growth after 1887. The improved prosperity of the south Wales coal industry from the late 1880s resulted largely from changes on the supply side raising the price of coal, and as productivity was the most powerful force on the supply side, it seems possible that declining productivity had some beneficial effects. Since falling productivity has traditionally, and understandably, been viewed as detrimental for coalmining in the years 1888-1913, the link from productivity to the fortunes of both coal owners and miners, and the British economy more generally, needs reappraisal.[24]

IV

For the south Wales coal owners falling productivity from the 1880s meant higher prices but less output and also increased costs, especially those of labour. The positive effect of falling productivity on the value of output was greater than the detrimental rise in costs, and the financial position of the owners improved after the 1880s. Using the least dramatic boundaries, which suggest productivity was responsible for 73 per cent of the difference between supply shifts in the periods 1874-87 and 1888-1913, implies the turnaround in productivity growth, at a minimum, reduced output growth by −0.49 per cent per annum and raised prices by 2.35 per cent per annum across the two periods. Thus real value of south Wales coal output grew at least 1.86 per cent per annum faster in the years 1888-1913 than in the period 1874-87 because of falling productivity. By itself falling productivity was more than sufficient to offset the deleterious effects of slower demand growth on the real value of output after 1887. Inelastic demand for south Wales coal in the years prior to 1914 led to productivity weaknesses accelerating growth in the real value of output.

Miners' wages, and hence the owners' costs, were intimately linked to the price of coal, either by a formal sliding scale or through the deliberations of

[24] Taylor, 'Labour productivity', provides the modern literature's starting point.

conciliation boards.[25] Since productivity by its impact on supply strongly influenced the price of coal, there was also a clear link from productivity to miners' wages and owners' costs.[26] South Wales miners' real wages were stagnant in the period 1874-87, and grew around 0.6 per cent per annum in the subsequent years to 1913.[27] Even within the years 1888-1913 productivity decline played a major role in increasing wages. Every one per cent increase in the relative price of coal raised real wages by 0.66 per cent.[28] Since the real price of coal increased 0.94 per cent per annum between 1888-1913, the implied wage growth of 0.62 per cent per annum closely approximates the actual rate. Negative supply curve shifts, and continued demand growth - albeit at a slower pace – were responsible for higher coal prices and hence rising wages in the years after 1887. Supply shifts were only responsible for 27 per cent of the increase in real coal prices within the years 1888-1913, since the inflationary effects of falling productivity and rising factor prices were partially offset by capital stock expansion. But by itself falling productivity reduced supply by at least −2.63 per cent per annum in the period 1888-1913, sufficient to raise coal prices by 0.59 per cent per annum, and real wages by 0.39 per cent per annum - equivalent to 65 per cent of the actual wage rise. However continued demand growth after 1887 had a stronger effect on real wage growth within the period 1888-1913, than did falling productivity. Demand shifts raised coal prices and miners wages by 0.68 and 0.45 per cent per annum respectively in the years 1888-1913.

Yet the sea change in the prosperity of coal owners and miners between the periods 1874-87 and 1888-1913 did stem from the reversal of the productivity trends, since demand growth was slower in the more prosperous later years. The key elements underpinning the transformation in the market for south Wales coal were inelastic demand and a dramatic turnaround on the supply side. Slower demand growth's tendency to reduce coalmining's prosperity after the 1880s was overwhelmed by the price reversing effects of a shift from fast to negative growth of supply, as productivity peaked in the 1880s and then fell. The net effect for coal owners in the years prior to 1914 were clearly favourable. The implied output fall was more than offset by the price upturn, and growth in the real value of output accelerated. Costs did rise, but at a slower pace than the real value of production. Wages grew at

[25] See especially TREBLE, 'Sliding scales', and also GREASLEY, 'Diffusion', p. 264.

[26] Most analysts, see HIRSCH and HAUSMAN, 'Labour productivity', stress the influence of wages on productivity, although GREASLEY, 'Wage rates', takes the alternative view.

[27] MITCHELL, *Economic development*, pp. 192-249. Wages did fluctuate substantially around trend.

[28] The figure results from a simple regression of coal's price and wages. For the years 1874-1913, $\log W = 0.39 + 0.66 \log P$; $R^2 = 0.77$, D.W. = 0.87. For the period 1888-1913, $\log W = 0.41 + 0.66 \log P$; $R^2 = 0.77$, D.W. = 1.77.

only two thirds the pace of prices in the period 1888-1913, and it seems unlikely that other costs grew so quickly as wages.[29] Real wage growth from the late 1880s was however sufficient to bring major improvements in the fortunes of coal miners since their real wages were stagnant in the years 1874-87.

In the pre-1914 demand environment falling productivity benefited those within the coal industry, both the owners and miners. For the British economy more generally the consequences of falling coalmining productivity were more problematical. Matthews, Feinstein, and Odling-Smee identify mining as second only to agriculture in retarding the British economy's productivity growth in the period 1873-1913.[30] Indeed mining and quarrying was the only sector which consistently depressed the declining productivity growth rate within defined sub-periods in the four decades before the First World War.[31] So falling coalmining productivity did have costs, but these, given the price inelastic demand for coal in the years prior to 1914, were passed from the producers to consumers. Since half south Wales coal output was exported by 1913 much of lower productivity's cost was passed overseas, and Britain's terms of trade benefited from higher coal prices. While Britain's terms of trade with the rest of the world declined 3 per cent in the years 1900-13, they rose 8 per cent with industrial Europe, the chief focus for British coal exports.[32]

The social cost of falling south Wales coalmining productivity by 1913 can be approximated by considering the concomitant increase in the real price of coal over the previous quarter century. Using the maximum estimate of productivity decline suggests falling productivity, at most, raised price by 0.74 per cent per annum, or 20 per cent in the period 1888-1913. The Cardiff f.o.b. price of coal averaged £0.82 in 1913. Hence without the adverse productivity trend the 1913 price would have been, at least, £0.68 per ton. The £0.14 price differential between the actual price and that which would have prevailed in the absence of productivity decline, and a 1913 south Wales coal output level of 56.8 million tons, indicate a social cost of £7.95 million, or 0.37 per cent of 1913 national income. Half of this social cost would have been passed overseas. Even falling productivity in British coalmining generally does not appear to have presented a major problem for the British economy. Since around 20 per cent of British coalmining was located in south Wales the results suggest generally falling coalmining productivity would have cost no more (since south Wales experienced above average productivity decline in the years 1888-1913) than 1.85 per cent of national income in 1913,

[29] MITCHELL, *Economic development*, p. 290.

[30] MATTHEWS et al., *Economic growth*, p. 229. Their figures strictly relate to mining and quarrying.

[31] FEINSTEIN et al., 'Climacteric', p. 181.

[32] SAUL, 'Export economy, p. 9.

about one third of which would have been passed overseas. Similar calculations using the more plausible upper bound for productivity growth in the years 1888-1913 indicate a social cost in 1913 equal to 1.45 per cent of national income.

V

Quantitative appraisal of the market forces which shaped movement in south Wales coal output and price in the period 1874-1913 inevitably involves simplifying assumptions, but the results seem clear enough. The paradox, noted by Taylor almost thirty years ago, that coalmining prosperity was worse in the earlier years of higher productivity than in the era of productivity decline after the 1880s, can be readily explained by a simple analysis of demand and supply.[33] On the demand side the key finding indicates a marked price inelasticity of demand for south Wales coal. Thus shifts on the supply side mostly affected the price of coal. Conversely, since short-run supply conditions, given the labour intensity of coalmining, were price elastic, shifts in demand primarily impinged on coal output. Hence, although shifts in supply were the more volatile, slower output growth in the period 1888-1913 chiefly reflected a slowdown in demand growth, as retardation in steam shipping and the south Wales iron industry more than offset the effects of increased export growth to Mediterranean Europe. The financial fortunes of south Wales coalmining improved during the years of slower demand and output growth after 1887, since the downward trend in coal price was reversed, and growth in the real value of output accelerated. The dramatic negative shift in the short-run supply curve, largely associated with the onset of productivity decline, accounts for the favourable price trend from the late 1880s. Given the inelastic demand for south Wales' coal, the owners, and miners since wages were closely tied to price, benefited from negative productivity and supply-side shifts, since these led to faster growth in the real value of output. Consumers of coal were less favoured, but since half Welsh coal was exported by 1913, improvements in the terms of trade offset the cost to the British economy.

[33] Taylor, 'Labour productivity', p. 66.

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