A Hayekian Analysis of the Term Structure of Production

Robert F. Mulligan

The Hayekian triangle (Hayek 1931, p. 39; subsequently developed by Hayek 1941; 1966; 1969) is used to analyze the structure of production in the United States. Using 1959–2000 monthly data, the relationship between government security interest rates and resource employment in several production sectors is examined. When interest rates increase, the structure of production becomes less roundabout, redistributing productive resources away from producer goods toward consumer goods. When interest rates rise, higher rates of return in production are necessary to compete with financial instruments such as relatively higher-yielding government bonds. This is manifested in a shifting of resources from early to late stages of production and can be shown as a shortening of the base of the Hayekian triangle.

In the most stylized case, the interest rate is proportional to the slope of the hypotenuse of the Hayekian triangle. The steeper hypotenuse reflects the higher interest rate and consumers' increased time preference—in this higher-interest environment, consumers are less willing to wait for immediate consumption goods. Conversely, when interest rates fall, the structure of production becomes more roundabout, redistributing marginal resources

toward productive activities with lower rates of return. These more round-about production processes produce more final output but require more production time.

Although the Hayekian triangle is a general model of intertemporal resource allocation, it is generally interpreted as a model of how interest rates determine allocation of investment versus consumption spending, and how the structure of production is manifested in the capital stock. In this paper, Hayek's model of intertemporal production is tested using labor, rather than capital, as the productive resource. This approach is justified in two ways: (1) Hayek's is a general model of intertemporal resource allocation, tested here with labor data; or (2) labor data can also be considered a proxy for capital, which is more difficult to measure.

Lachmann (1978, pp. 2–4) noted that capital goods, unlike land and labor, lack a natural unit of measurement. Although the periodic rental payment equivalent—the amount capital goods yield for hire per hour or per month—technically can be observed, the size of the capital stock can only be estimated, as can the amount employed in different productive sectors. Consequently, this study uses more readily observable labor data. Labor market sectors examined include: manufacturing; construction; finance, insurance, and real estate; government; mining; services; transportation and public utilities; retail trade industry; and wholesale trade industry. Since the production process has both time and value dimensions in Austrian capital theory (Garrison 1978, p. 169; 2001, p. 46), industrial sectors representing predominantly early, middle, or late stages of production employ complementary land and labor resources as they expand or contract in response to interest rate changes over the business cycle.

The Hayekian triangle provides prior expectations about how employment levels in late and early stages of production should vary as interest rates change. Employment in late stages of production, such as retail trade industry, should be directly proportional to nominal interest rates. Employment in sectors predominantly representing early stages of production, such as mining, should be inversely proportional to the interest rate. Econometric estimation is used to test Hayek's model against these prior expectations. Some sectors are especially difficult to characterize a priori as early, middle, or late stages of production. This analysis provides an empirical rationale for classifying each sector by stage of production, independent of prior expectations.

Findings regarding labor market sectors are related to business cycle fluctuations and sectoral capital investment. According to Austrian capital theory, real interest rates are countercyclical (Garrison 2001, pp. 68–70). Employment in late-stage-of-production sectors is also countercyclical, while employment in early-stage-of-production sectors is procyclical. It should be noted that Austrian business cycle theory hinges far more fundamentally on policy-induced changes in the interest rate, which drive the cycle, than on distinctions between real and nominal interest rates or between anticipated and unanticipated changes in the price level. Furthermore, in the Austrian view,

though preference-induced changes in interest rates affect resource allocation, they do not cause a business cycle.

This paper also attempts to approximate the time-to-maturity for each production sector, by analyzing which of several long-, medium-, and short-term interest rates employment in each sector responds to most closely. Because the structure of production, represented by the base of the Hayekian triangle, shortens and lengthens over time as interest rates change, it is often particularly difficult to associate a particular maturity with early and middle stages of production.

The rest of the paper is organized as follows. The theoretical basis for the paper is briefly developed in "The Hayekian Theory of Production Structure." Data sources are documented in "Data." "Cointegration Analysis" presents the empirical work, based on a decomposition of the labor market into nine industrial sectors, and presents tests for cointegration, followed by estimates of cointegration spaces normalized with respect to interest rates. Concluding comments are presented in "Conclusion."

THE HAYEKIAN THEORY OF PRODUCTION STRUCTURE[1]

At each stage of production, the value of the objects of productive activity, also called goods-in-process, working capital, or producer goods, is related to both the value of the consumable output into which it may be transformed and the time required to complete the transformation (Hayek 1967, pp. 37–47; Garrison 1985, p. 166; 2001, pp. 46–49). This value is the expected future value of the consumable output, discounted to the present over the expected remaining production time. Ideally constructed, the discount rate is the rate of time preference or natural rate of interest, not any observed nominal interest rate. Entrepreneurial planners actually perform time discounting with prevailing market nominal interest rates representing their opportunity cost, rather than subjective rates of time preference. These objectively observable interest rates are more likely to reflect actual, subjective time preferences if they are not being manipulated by the central bank. Entrepreneurs are free to adjust production plans, and do so in response to technological advances; disappointed expectations about resource availability and cost, or about output demand and price; and changes in interest rates.

The concept of stages of production is subjective (Garrison 1985, p. 167; 2001, p. 46), thus specific industries often operate simultaneously in several different stages, and any empirical classification of industrial sectors can only be of which stage predominates. For example, coal used for home heating represents a later stage of production than coal burned in a blast furnace. Furthermore, many resources, including producer goods, are nonspecific to a particular stage of production. Because each industry can use many resources

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[1]This section briefly summarizes the Austrian capital theory on which the empirical work presented in the section "Cointegration Analysis" is based.

in multiple processes, industries often operate simultaneously in different stages of production.

Capital goods may substitute or complement other capital goods. Furthermore, this is a general property of all resources; for any capital good, labor may be either a substitute or a complement; different kinds of labor may be substitutes or complements for a given capital good, or for other given kinds of labor. Different productive resources also have various degrees of substitutability and complementarity (Garrison 1985, p. 168; 2001, p. 49). Inputs are combined at each stage of production. Stages of production are not instantaneous; thus time preference assures that outputs from each stage have greater expected value than the sum of inputs (Mises 1966, pp. 483–88; Rothbard 1970, pp. 323–32; Garrison 1985, p. 169; 2001, p. 46). Inputs do not produce surplus value and are not productive in the classical sense, but the task of coordination performed by entrepreneurial planners is essential for production to take place. In the Austrian view, the increase of value in production over time is due exclusively to:

1. the time span required for each stage of the production process,

2. the fact of time preference, which discounts the inputs into each stage, compared to the expected output from each stage, and

3. the value consumers confer on the final output, which they use to satisfy their wants.

The interest rate is the rate of time discount implicit in the pattern of prices of productive resources, including capital goods. Garrison cautions (1985, pp. 169–70; 2001, p. 50) this is not necessarily the same as the loan rate determined in the loanable funds market, though he also acknowledges the market process eventually adjusts the loan rate to the broader market rate of interest. In the Austrian view, determinants of the broader market interest rate are not exhausted by the determinants of the loan rate in the loanable funds market (Rothbard 1970, pp. 321–23), although the slope of the hypotenuse of the Hayekian triangle reflects the interest rate determined in the loanable funds market (Garrison 2001, p. 50).

The value of inputs is determined by the price an entrepreneur expects to command for output at the end of the stage of production, whether for sale to a consumer or to a producer who uses output from an earlier stage as input in a later stage. This expected price of the entrepreneur's output is discounted over the duration of the entrepreneur's stage of production (Garrison 1985, p. 170; 2001, p. 46). The discount rate connecting the prices of intermediate outputs produced in early, middle, and late stages should reflect the rate of time preference in the absence of central bank intervention.

Garrison (1985, pp. 171–76; 2001, pp. 57–67) attributes changes in secular growth rates and the distribution of output between consumption and investment goods to changes in liquidity preference, changes in labor supply due to changes in labor-leisure preferences, and changes in technology. The Austrian

theory of the business cycle attempts to subsume the effects of both kinds of changes in preferences in an encompassing theory based on artificial changes in interest rates mimicking changes in time preference (Garrison 1985, p. 177; 2001, pp. 67–71). Monetary expansion, which lowers the interest rate, brings about a shift in apparent time preference away from current consumption toward future consumption. Monetary contraction has the opposite effect. The earlier the stage of production, the greater the period of time separating existing capital or producer goods from the prospective consumer goods, and the greater the difference in value due to time discounting between producer and consumer goods. Thus the value of early-stage producer goods is more sensitive to interest rate changes (Garrison 1985, pp. 178–77; 2001, p. 72).

When time preference decreases, this is signaled immediately by a reduction in nominal and real interest rates because there is an immediate and corresponding decrease in the natural rate of interest, on which all real and nominal interest rates are based. Productive resources are reallocated from late stages to early stages of production. New, earlier stages are created, extending production structure. But because this reallocation is effected by a change in preference for current as opposed to future consumption, the height of the triangle must eventually increase to reflect higher future consumption levels.

Hayek (1967, pp. 136–39) and Garrison (1986, p. 440; 1988; 2001, pp. 71–73) draw a fundamental distinction between ordinary changes in time preference and policy-induced changes in interest rates. Normal changes in time preference do not cause the business cycle. Austrian capital theorists construct a malinvestment-misallocation argument to explain how policy-induced changes in interest rates cause the business cycle. As interest rates fall in response to central bank injections of new money, the artificially low interest rate drives a wedge between saving and investment. Increased saving entails an initial contraction of consumer-good industries. In contrast, however, credit expansion lowers interest rates, simultaneously reducing the attractiveness of saving and causing potential savers to spend more of their income on consumer goods. Mises (1966, pp. 550–66) develops a similar argument. In Mises's view, when the central bank expands the supply of money or credit, it signals a decrease in the real interest rate, but not necessarily the nominal interest rate. Hayek characterizes artificial booms engineered through monetary expansion as working through malinvestment and forced saving; Mises characterizes these booms as working through malinvestment and overconsumption. In fact, both overconsumption and forced saving accompany the malinvestment of the policy-induced boom in turn. The Misesian overconsumption boom occurs first, as consumers who save less in response to the unattractively low interest rate consume more. The Misesian overconsumption boom may be prolonged if entrepreneurs are sufficiently alert to opportunities afforded by the credit expansion. Once the economy exhausts its ability to reallocate resources from middle to late stages of production to provide additional consumption goods desired by consumers, the Hayekian forced saving boom begins.

It is important to stress that Austrian capital theory does not rely on the Fisherian distinction between real and nominal interest rates or the distinction between anticipated and unanticipated changes in the general price level. Instead it emphasizes a distinction between preference-based changes in interest rates and policy-induced changes. It does not matter whether these two kinds of changes in interest rates are affected by, or accompanied by, changes in the general price level.

When interest rates fall, households save less in response to the less attractive yield, and demand more final output for immediate consumption. At the same time, firms borrow more at low interest to finance new productive resources, and they reallocate resources, including complementary labor, toward early stages of production. Thus the Hayekian triangle simultaneously becomes steeper, or less roundabout, for late stages, and flatter, or more roundabout, for early stages. The policy of monetary injection drives a wedge between saving and investment in the loanable funds market. Households save less and consume more in response to the lower interest rate, demanding more late-stage consumer goods. Entrepreneurs respond to the additional demand for consumer goods by reallocating resources toward late stages of production. But the monetary injection drives down the interest rate and makes more funds available for investment, even in the absence of additional saving. Entrepreneurs allocate these funds to early stages of production. The production structure simultaneously extends average production time and attempts to increase the amount of output supplied to consumers. Hayek (1967, p. 137) describes this concave "triangle" as curvilinear.

The Misesian overconsumption boom occurs first, when firms initially respond to the increased demand for consumers' goods with a secondary reallocation away from middle-stage production toward late-stage. The Hayekian forced saving boom occurs soon after, when consumers are saving less in response to the lower interest rate and begin demanding more output for immediate consumption, while firms are still responding to the lower interest rate by reallocating away from late-stage production (consumer goods) toward early-stage production (producer goods). This gives the curvilinear Hayekian triangle its "pinched in the middle" shape characteristic of an unsustainable monetary or credit expansion boom. The production structure cannot continue to deliver the high level of late-stage consumer goods, given the amount of resources distributed over early and middle stages, and generally the lower-yielding resources employed in early and middle stages of production are producing intermediate inputs that will be abandoned as soon as the interest rate rises back to a sustainable level.

During the boom caused by a policy-induced credit expansion, the curvilinear triangle does not reflect individuals' true time preferences. The interest rates prevailing in, and discounting inputs from outputs of, each stage—lower in early stages and higher in late stages—no longer reflect the natural rate of interest. This applies to both real and nominal interest rates, and the credit-induced curvilinear production structure is never sustainable. Because the

structure of production ultimately responds to unsustainably low interest rates by simultaneously attempting to deliver more consumer goods in the late stages and more producer goods in the earlier stages, different maturity interest rates have to be considered, corresponding approximately to the variable duration of the production structure.

This paper assumes that virtually all intertemporal resource allocation accompanying changes in interest rates is due to expansionary monetary policy. If resource reallocation occurred because of changes in intertemporal consumption preferences or technological change, that reallocation should not be systematically related to interest rates, especially nominal interest rates. In the sample period of over 40 years, dramatic technological advances and changes in consumer time preference certainly occurred, due, for example, to demographic changes in age distribution. Unlike policy-induced credit expansion, these factors do not play any systematic role in driving the business cycle. Technological change is generally interest-neutral (Garrison 2001, pp. 59-62), while credit expansion never is. Also, like technological change, changes in time preference never cause unsustainable reallocation of productive resources.

DATA

This section documents the data used for econometric estimation and motivates the choice of data. The U.S. Department of Labor provides seasonally adjusted monthly sectoral employment data for 1959–2000. The percent employed in each sector is sectoral employment divided by the labor force.[2]

Interest rates for several maturities, ranging from three months to five years, were used to capture the apparent implicit time preference latent in the nominal term structure. Interest rates influence productive activity in several ways, over several different periods, listed from shortest to longest duration:

1. duration of the productive process,

2. installation period for productive capital, or

3. expected useful life of installed capital.

Shortest maturities were chosen in the first instance because they are more relevant for determining short-run resource allocation, and in the second instance for parsimony. Furthermore, the first and shortest set of interest maturities is more relevant for determining labor allocation. This is a general feature of the labor market, whether specific labor services are complementary with, or substituted for, given capital equipment. This circumstance arises from the fact that entrepreneurs adjust production plans through varying the

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[2]The Federal Reserve Bank of St. Louis provides interest rates. Three-month, six-month, and one-year Treasury bill secondary market rates and three-year and five-year constant maturity rates are taken for the same period. All data are from the Federal Reserve Bank of St. Louis Federal Reserve Economic Data (FRED) Web site.

composition and quantity of labor once they are no longer free to adjust the quantity and use of installed capital. Labor employment adjusts in response to short-term interest rates. Entrepreneurs would not adjust capital use except in response to changes in interest rates of maturities at least as long as the minimum capital installation period or lease-term. Because sectoral employment rates are used both as proxies for capital structure and to capture the general level of productive activity in different sectors, labor wage rates are not included in this analysis. This paper examines the extent to which general productive activity, measured by sectoral labor employment, responds to interest rates of various maturities.

Cointegration Analysis

This section presents and interprets empirical estimates based on the Hayekian triangle using interest and employment data. In interpreting empirical results, it must be kept in mind that productive resources do not flow to the most productive activities of their own accord. Workers offer their services on the labor market in response to higher relative wages and lowered opportunity costs. Entrepreneurs construct and adjust the structure of resource allocation and production in response to expected consumer demand for consumable output and expected opportunity cost.

In the subjectivist theory of a capital-using economy, entrepreneurial planners act as the subjects of productive activities, creating consumable output as the object (Garrison 1985, pp. 164–65; 2001, p. 15). Consumers confer value on consumable output because they desire it to satisfy their wants. The value of producer goods is derived from the consumable output they are expected to yield and expected consumer demand for the output. The earlier that entrepreneurs intervene in productive activity, the greater the opportunity to increase the final yield of consumable output. Thus the final output should be greater in value the more roundabout the production process. This intuition is supported by the general observation that the more roundabout the production process, the greater the scope for employment of capital.

Interest rates facilitate intertemporal coordination of productive resources by clearing the loanable funds market (Garrison 1986, p. 440; 2001, p. 39). In this regard, disequilibrium interest rates play the same role as prices in signaling opportunities for entrepreneurial discovery (Kirzner 1992b, p. 146; 1992c, pp. 160–61; 1997), and individual entrepreneurs respond by maintaining the production structure, that is, they adjust it by reallocating resources.

Installed vs. Financial Capital in Entrepreneurial Plans:
Bischoff's Putty-clay Model

Bischoff (1970) presents a valuable distinction between uninvested financial capital and installed physical capital: the "putty-clay" model. In his formulation, "putty" capital is uninvested saving that helps clear the loanable funds market. "Clay" capital has already been installed, and is expected to

yield a definite return in currently operating entrepreneurial plans. This expected return must be at least as high as the return on financial assets, such as government bonds, available to entrepreneurs when they formed their production plans. The actual return on installed capital may be lower, as expectations may be disappointed.

When interest rates change, this impacts entrepreneurial decisions about whether and where to invest "putty" capital. "Clay" capital, which is already installed, may be abandoned completely, or may be used exactly as called for in the original production plan. Most commonly, however, "clay" capital is used in modified production plans, which attempt to extract as high a return as possible (Garrison 2001, p. 74). The available "clay" capital was intended for a different production plan, predicated on a different interest rate, for a given maturity corresponding to the useful life of the installed capital.

In Keynesian terms, there is a liquidity constraint on "clay" capital, in contrast to uninvested "putty" capital. If investors could take their funds directly out of installed capital and invest these funds in higher-yielding government bonds or other financial assets, they would, but these funds are tied up in illiquid physical assets, or in term leases on physical assets. These physical assets may be sold, but they cannot command as high a price once their productive yield becomes less competitive. The objective of empirical examination of the term structure of labor markets is to search for evidence of such adjustment of the production structure.

Unit Root and Cointegration Tests

Most economic time series display an increasing trend, and unit root tests were developed to identify this characteristic. Stationary time series are said to have zero roots, or to be integrated of order zero [I(0)]. Nonstationary series may have a unit root or be first-order integrated [I(1)]. Unit root series become I(0) when first-differenced. Regressions estimated with nonstationary data will not have the white-noise residuals needed for valid inference. The regression could be estimated in first-differences, but then any long-term information carried by the levels of the variables is lost. Error-correction models overcome this difficulty by estimating a regression in first-differences augmented by error-correction terms, the lagged differences between the actual and estimated value of the left-hand-side variable, collectively referred to as the error-correction process, or the disequilibrium adjustment process. The coefficients on the first-differenced variables constitute the cointegrating vector or structural relationship. A sufficient number of lagged error-correction terms is added to guarantee white-noise errors and valid inference (Davidson and McKinnon 1993, pp. 720–30; Kennedy 1998, pp. 266–70).

Estimation with error-correction models is of special interest to the Austrian School because under ideal conditions, the technique provides estimates of both a structural or equilibrium process—which adjustment is always effected toward, though it may never be perfectly realized—and the error-correction or disequilibrium adjustment process, through which adjustment is

made toward the hypothesized equilibrium. Even if one rejects the reality of any hypothesized equilibrium, estimates of the disequilibrium adjustment process would still carry interest.

Because of the length of the data set, the Johansen-Juselius (1990) procedure was used to identify stable, long-term relationships among the sectoral employment and interest rates. Table 1 reports Phillips-Perron (1988) unit-root tests for each variable. All are found to have unit roots. When the test regression is estimated with an intercept but no trend, the null hypothesis of a unit root [I(1)] is never rejected at conventional significance levels for employment levels calculated as percentages of the labor force, or for the interest rates. When a linear trend is added to the test regression, the same result is observed, except for mining, where the I(1) null is rejected at the 5-percent level, but not at the 1-percent level. The finding that mining may be I(0) indicates it might be deleted from the vector error-correction model, but mining was retained in the model because it remains a part of the nation's employment statistics, though declining in importance throughout the sample period, and because there is some support for the conclusion that mining is I(1). The null hypothesis of a unit root is always rejected for the first-differenced series, demonstrating all are integrated of order one [I(1)] and not of higher order.

Somewhat surprisingly, the interest rates are found to be I(1). A priori, interest rates are expected to be I(0). This would not present any difficulty for interpreting vector error-correction models that include I(0) interest rates and I(1) employment rates, because in order for the I(1) employment rates to enjoy stable, long-run relationships with any I(0) series, the employment rates would have to be cointegrated. Since more than five cointegrating vectors are found, there must be some cointegration among the employment rates.

Table 2 reports Johansen-Juselius tests for cointegration. The data matrix includes the nine sectoral employment rates and the five interest rates, a total of 14 variables. Results provide very strong evidence of cointegration and indicated very strong, very stable, cointegrated relationships among 13 cointegrating vectors.

Likelihood ratio tests were unable to determine the optimal lag length for the disequilibrium adjustment process. Thirty lags were used to ensure white-noise residuals and unbiased estimates of the long-run structural process measured by the cointegrating vectors. Because the estimate may have used shorter than optimal lag structure, the estimate of the disequilibrium adjustment process is merely suggestive. Attention therefore focuses on the structural or equilibrium process.

The Cointegration Space

With 13 cointegrating relationships identified, it becomes necessary to focus on those that can be given economic interpretation. The normal practice is to examine the largest-dimensioned cointegrated space, but in this case that would explain only one of the 14 variables, which would have little interest. From a Hayekian perspective, two sets of cointegrating vectors are of interest:

1. Five cointegrating vectors normalized with respect to the five interest rates. These five equations indicate how employment in each of the nine industrial sectors responds to changes in each interest rate.

2. Nine cointegrating vectors normalized with respect to sectoral employment. These nine equations would indicate how changes in the different interest rates affect employment in each sector.

Table 1
Phillips-Perron Test for Sectoral Employment Rates
and Secondary-market
Government Security Rates: 1957:07–2000:01

Sector	Levels		First-differences	
	Intercept	Intercept + trend	Intercept	Intercept + trend
Mining	-0.221	-3.607	-13.351	-13.409
Construction	-0.190	-0.426	-13.639	-13.753
Manufacturing	-1.719	-1.522	-11.571	-11.691
Wholesale	-1.149	-1.065	-14.887	-14.895
Finance, Insur. Real Estate	-2.287	-1.670	-15.568	-15.699
Transportation Utilities	-1.911	-1.822	-31.058	-31.771
Government	-2.440	-1.922	-16.299	-16.498
Services	2.474	-1.214	-17.285	-17.737
Retail	-0.335	-1.366	-16.034	-16.012
Goods prod. Industry	-1.535	-1.536	-11.367	-11.463
Service prod. Industry	-1.261	-1.428	-18.811	-19.024
3-Month T Bills	-2.505	-2.460	-15.271	-15.258
6-Month T Bills	-2.394	-2.355	-15.070	-15.056
1-Year T Bills	-2.292	-2.267	-14.739	-14.723
3-Year T Note	-2.044	-1.985	-14.911	-14.898
5-Year T Note	-1.920	-1.823	-14.602	-14.591
Critical values	1% -3.4567 5% -2.8726 10% -2.5726	1% -3.9961 5% -3.4282 10% -3.1372	1% -3.4568 5% -2.8726 10% -2.5726	1% -3.9962 5% -3.4282 10% -3.1372

The five-equation model, where the dependent variables are interest rates, is reported in Table 3. Each cointegrated vector is normalized with respect to, and solved for, different interest rates with maturities ranging from six months to five years. Cointegrated vectors are solved for the interest rate to which they are normalized. This facilitates interpretation of the coefficients by producing opposite signs for each coefficient, compared to how most statistical softwares represent cointegrated vectors.

Results are unambiguous. No mixed signs are observed for different-maturity interest rates for any employment sector. Many of the coefficients are statistically significant at conventional levels; thus the reported equations and coefficient estimates possess significant information content. The coefficients are interpreted as inverse elasticities of employment with respect to interest.

Table 2
Tests for Cointegration
Detailed Decomposition of Employment 1959:7-2000:1

Maximum Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized # CE(s)
0.957328	6936.817	233.23†	247.18†	None*
0.890824	5498.500	233.13†	247.18†	At most 1*
0.854506	4488.555	233.13†	247.18†	At most 2*
0.791594	3609.560	233.13†	247.18†	At most 3*
0.755817	2894.429	233.13	247.18	At most 4*
0.698060	2251.544	192.89	204.95	At most 5*
0.627711	1705.473	156.00	168.36	At most 6*
0.594622	1254.906	124.24	133.57	At most 7*
0.472312	843.1676	94.15	103.18	At most 8*
0.392558	551.6694	68.52	76.07	At most 9*
0.291503	324.3541	47.21	54.46	At most 10*
0.198647	167.2121	29.68	35.65	At most 11*
0.132597	66.22935	15.41	20.04	At most 12*
0.002984	1.362635	3.76	6.65	At most 13

* denotes rejection of the null hypothesis at the 1 percent significance level

† denotes critical values derived assuming 10 endogenous series

Johansen-Juselius Likelihood Ratio test indicates 13 cointegrating equations at 5 percent significance level

30 lags were used in the disequilibrium adjustment process

Table 3
Vector Error Correction Model:
Five Cointegrating Vectors Normalized with Respect to Interest Rates

	C	Mfg.	Con.	Fin.	Gov.	Svs.	Min.	Trns.	Ret.	Whl.
3M	-416.448	-41.5593	-1941.17	-1227.24	-662.917	-96.1149	4440.42	2302.548	2413.742	4012.685
		(85.48)	*(555.48)	*(560.62)	*(183.39)	(68.26)	*(384.06)	*(744.50)	*(504.41)	*(1641.98)
6M	-383.374	-17.1459	-1736.08	-1025.23	-584.134	-74.9355	4373.523	2044.955	2210.23	3416.729
		(76.76)	*(498.76)	*(503.38)	*(164.66)	(61.29)	(344.84)	*(668.47)	*(452.90)	*(1474.32)
1Y	-348.574	-9.89709	-1584.86	-883.025	-520.303	-67.3124	4044.224	1821.103	1996.844	3084.589
		(68.51)	*(445.19)	(449.31)	*(146.98)	(54.71)	*(307.80)	*(596.67)	*(404.26)	*(1315.96)
3Y	-415.88	-87.3708	-2214.64	-1052.7	-652.031	-153.391	3996.892	2523.663	2412.808	4284.866
		(83.82)	*(544.67)	(549.71)	*(179.82)	*(66.93)	*(376.58)	*(730.00)	*(494.59)	*(1610.02)
5Y	-439.355	-114.203	-2520.7	-1123.61	-724.553	-194.72	3901.23	2825.141	2648.53	4593.424
		(91.19)	*(592.53)	(598.02)	*(195.62)	*(72.82)	*(409.68)	*(794.16)	*(538.05)	*(175.51)
Conclusions		←———— Early procyclical ————→				←——→	←——— Late countercyclical ———→			

Log likelihood = 42046.84.
Standard errors in parentheses.
*Indicates significance at the 5 percent level.

Hayekian Classification of Industrial Sector
by Stage of Production

A positive relationship between an employment rate and an interest rate indicates a late stage of production; a negative relationship indicates an early stage. Table 3 indicates that mining; transportation and utilities; retail trade industry; and wholesale trade industry are late stages of production, and that manufacturing; construction; finance, insurance, and real estate; government; and services, are early stages. The one odd finding is that mining is late stage of production.

Cointegrating vectors always have negative coefficients on employment in manufacturing; construction; finance; government; and services, indicating employment in these sectors falls whenever interest rates rise. Negative inverse-elasticities of employment indicate early stages of production.

For manufacturing, none of the negative inverse-elasticities are significant at conventional levels. This result suggests early-stage production but does not provide convincing evidence. In contrast, for construction and government, all the negative inverse-elasticities are statistically significant, providing strong evidence that these are early stages. For services, negative inverse-elasticities are significant for three-year and five-year interest rates, but not for shorter maturities. This indicates early-stage production, but also indicates that employment in services responds only to long-term interest rates, which is not surprising for early-stage production, which must be more roundabout by definition.

For finance, insurance, and real estate, negative inverse-elasticities are significant for three-month and six-month interest rates, but not for longer maturities. This outcome is very interesting. Statistical evidence supports the characterization of the financial sector as an early stage of production, but in contrast to the service sector, resource employment in the financial sector responds only to short-term interest rates. One reason for the difference between services and finance, which are both early stages of production, may be the lack of capital intensity in the financial sector. Service-sector producers maintain large and expensive capital stocks and are less free to adjust the size of their workforces. Financial, insurance, and real estate employers are less dependent on capital equipment and do adjust workforce size very quickly to accommodate changing business climates. In addition, finance employers face demand that responds more directly to short-term interest rates than demand faced by service employers.

Transportation, wholesale trade industry, retail trade industry, and mining have positive inverse-elasticities, which are always significant at conventional levels, across all maturities. This indicates unambiguously that these four sectors are late stages of production. The result is not surprising for transportation, retail, and wholesale, but it is somewhat so for mining. If any sector could be identified a priori as early stage of production, it would be mining. However, many high-value mining activities like petroleum production and field services are clearly late stages, temporally if not conceptually.

If less aggregated employment data were readily available for mining, it would be possible to test whether this accounts for the late-stage finding and whether the data confirm that refining is later-stage than mining strictly defined. Mining consists of slow and fast activities, just as slow-growing trees represent higher-order, earlier-stage production, and fast-growing trees are lower-order and late-stage. For example, coal may be delivered and burned to heat homes relatively quickly after being mined, with a minimum of intermediate processing, which would constitute late-stage production. The same mine could also produce coal for steel mills and other sophisticated concerns that use the coal in complex and time-consuming industrial processes, a form of early-stage production. Thus the same production can be either early or late stage depending on whether the output is sold to a final consumer or another firm. It may simply be that fast, late-stage mining activities predominate, or, because labor data is examined here, that fast mining activities are merely more labor intensive.

A further possibility may be that when interest rates fall due to credit expansion, mining concerns find it easier to work existing infrastructure to capacity and possibly beyond, increasing both output and labor employment, than to expand the infrastructure. If this were the case, mining firms would act more like late-stage producers, even while producing primarily in early stages. Their behavior would be atypical and largely attributable to the circumstance that the primary way to expand early-stage mining operations would be to construct new mines, not expand existing ones.

Interestingly, standard errors for wholesale are typically over three times greater than for retailing. This supports the common-sense conjecture that retailing is more clearly late stage of production than wholesale.

Sectoral Employment over the Business Cycle

Results can be related to the business cycle. Employment is countercyclical with output in predominantly late-stage-of-production sectors: mining, transportation and utilities, retail, and wholesale. Employment is procyclical in predominantly early-stage-of-production sectors: manufacturing, construction, finance, government, and services. Evidence for procyclicality in manufacturing is weak, as none of the inverse-elasticities is significant, though all are negative. Evidence is much stronger for construction and government. Evidence for procyclicality in services is strong, because it comes from significantly negative three- and five-year inverse-elasticities.

Evidence for finance is curious. Inverse-elasticities are significant and negative for three- and six-month maturities, indicating early-stage production which responds to short-term interest rates. Financial sector employment is procyclical, but only in response to short-term interest rates. Impulse response functions were examined but did not appear to follow any particular structure. The adjustment process is very long–over three years.

CONCLUSION

This paper presents very strong evidence of cointegration among sectoral employment and interest rates. Very strong evidence is also found for classifying mining; transportation and utilities; retail trade industry; and wholesale trade industry, as late stages of production, and manufacturing; construction; finance, insurance, and real estate; government; and services as early stages.

Cointegration analysis is applied to identify stable long-term relationships among employment rates and interest rates. The cointegrating relationships are stable equilibria entrepreneurial planners have generally effected adjustment toward during the 1959–2000 observation period. These equilibria are not necessarily ever realized, and in light of the long time indicated by the impulse response functions, it appears unlikely they are ever fully realized. The market process consists of entrepreneurial planners effecting adjustment toward a dynamic equilibrium they continuously redefine. The prevailing term structure of interest rates determines resource allocation among early, middle, or late stages of production, in accordance with consumers' time preference and available investment alternatives. Estimates of stable long-run cointegrated vectors using U.S. data provide convincing support for the Hayekian triangle as an encompassing explanation of intertemporal resource allocation and production.

Strong evidence is presented for countercyclicality of mining, transportation and utilities; retail; and wholesale. Employment in these predominantly late stage-of-production sectors generally increases with higher interest rates. In contrast, manufacturing; construction; finance, insurance, and real estate; government; and services, are procyclical. Employment in these predominantly early-stage-of-production sectors falls in response to higher interest rates. Thus, the expansion phase of the business cycle has been marked by a relative redistribution of employment into manufacturing; construction; finance, insurance, and real estate; government; and services out of mining; transportation and utilities; retail; and wholesale. Early-stage industries grow more rapidly during expansions, but they also shrink more rapidly during recessions. During a recession, employment generally falls in late-stage sectors of mining, transportation and utilities, retail, and wholesale but falls more rapidly in early-stage sectors of manufacturing; construction; finance, insurance, and real estate; government; and services.

Empirical analysis and interpretation of employment and interest data based on the Hayekian triangle have proved highly fruitful in revealing new information about the structure of U.S. production. Statistical inference has demonstrated the Hayekian triangle's strong explanatory power. Demonstration of stable, long-run equilibrium relationships among sectoral employment rates and interest rates indicate the data used are amenable to this kind of analysis.

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