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Where Have All the Jumbo Covered Hopper Cars Gone? An Investment Analysis of the U.S. Rail Grain Car Fleet

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Investment in jumbo covered hopper railcars (designated as C113s by the Association of American Railroads) plunged in the 1980s. The objectives of this study are to specify and estimate a model of C113 investment and employ the model to explain the C113 purchasing dearth of the 1980s. The model is a partial adjustment autoregressive model estimated with annual data for the 1964-91 period. The model does a good job of explaining Class I railroad C113 investment but a poor job of explaining private carriage (shippers and railcar leasing companies) C113 investment. The decline in C113 investment during the 1980s was partly caused by a decline in the real railroad price per carload of C113 commodities, high real interest rate levels, and increasing average tons per carload of C113 commodities.

ABSTRACT

Investment in jumbo covered hopper railcars (designated as C113s by the Association of American Railroads) plunged in the 1980s. The objectives of this study are to specify and estimate a model of C113 investment and employ the model to explain the C113 purchasing dearth of the 1980s. The model is a partial adjustment autoregressive model estimated with annual data for the 1964-91 period.

The model is estimated for Class I railroads, private carriage (shippers and railcar leasing companies) and the total of these two groups. The explanatory variables are the real price of C113s; the real railroad price per carload of C113 commodities; real interest rates; C113 acquisitions, lagged one year; tons per carload of C113 commodities, and a technological change dummy variable. Elasticities are calculated for each of these variables as well as the railcar stock adjustment period.

The model does a good job of explaining Class I railroad C113 investment but a poor job of explaining private carriage investment. The decline in C113 investment during the 1980s was partly caused by a decline in the real railroad price per carload of C113 commodities, high real interest rate levels, and increasing average tons per carload of C113 commodities.

INTRODUCTION

Railroad transportation plays an important role in U.S. grain logistics systems. In 1985, railroads transported 62 percent of the interstate wheat shipments (Reed and Hill, 1990), 47 percent of the interstate corn shipments (Fruin et al, 1990), 25 percent of the interstate soybean shipments (Larson et al, 1990), and 48 percent of the interstate sorghum shipments (Hill et al, 1990). Since many of the grain production areas are remote from major markets, the cost and availability of rail transportation has a significant impact on producers' incomes and the economic vitality of rural communities.

Historically, equipment availability has been one of the most controversial aspects of rail grain transportation. This is perhaps more true today than ever before. This year the Interstate Commerce Commission initiated an investigation of the nation's grain car supply problems. Areas to be explored in the investigation include rail car pooling and allocation practices, car problems of short line railroads, car adequacy for small grain elevators and rural communities, the impact of NAFTA on grain car adequacy, private car issues, and characteristics of the nation's grain car fleet.

Norton and Klindworth (1989) examined the ability of the current and projected grain car fleet (specifically jumbo covered hopper cars) to meet the future transportation needs of grain shippers. In the study's most likely scenario, significant car deficits would occur in the mid 1990s and would increase in severity until the end of the century.

Of course, the problem of short term, seasonal grain car shortages is not new, but rather a regular feature of grain harvest seasons. Babcock and Sorenson (1982) identified several causes of disequilibrium in the Kansas wheat logistics system including inflexible storage and transportation prices, wheat market information gaps, significant and unpredictable variation in the demand for rail transport in both production areas and at markets, and short run inflexibility of rail car supply and grain storage.

However, there is evidence of structural rail grain car supply deficits that are more fundamental than those associated with harvest seasons. Jumbo covered hopper cars are employed to move virtually all of the grain transported by rail. These cars, designated as C113 by the Association of American Railroads (AAR), are defined as covered hopper cars with gravity discharge unloading and a load capacity between 4000 and 5000 cubic feet. Between 1970 and 1981, Class I railroad annual additions to the C113 fleet totaled 74,216 (see Table 1). Between 1982 and 1991, C113 annual additions plunged to only 2438, nearly a 97 percent decline from the 1970-81 period. The same trend occurred for annual C113 additions by Private Carriage (shippers and rail car leasing companies) as their investment fell from 56,973 cars in the 1970-81 period to 17,307 for the 1982-91 interval, nearly a 70 percent decline.

As noted above, Norton and Klindworth (1989) have documented the plunge in C113 investment during the 1980s. While their study made important contributions to the description of the C113 fleet, it contained no C113 investment model that could be employed to explain the C113 purchasing dearth of the 1980s. An empirically estimated investment model could also be used to assess the likelihood of a continuation of the 1980s trends. Accordingly, the objectives of this study are:

1. Specify a model of C113 investment.
2. Empirical estimation of the C113 investment model specified in objective 1.
3. Based on the empirical findings of objective 2, explain the C113 purchasing dearth of the 1980s.

Table 1

CLASS I RAILROAD AND PRIVATE ANNUAL ADDITIONS OF C113 RAIL CARS*
1964-1991

Year	Class I Railroad Additions	Private Carriage Additions	Total C113 Additions
1964	3605	938	4543
1965	4488	420	4908
1966	5889	1328	7217
1967	7300	1650	8950
1968	2274	864	3138
1969	3083	861	3944
1970	4775	1883	6658
1971	6043	1015	7058
1972	3442	2474	5916
1973	9450	4138	13588
1974	5308	5794	11102
1975	4586	2554	7140
1976	2971	192	3163
1977	3458	856	4314
1978	4590	5103	9693
1979	7337	14199	21536
1980	14861	13628	28489
1981	7395	5137	12532
1982	661	1356	2017
1983	92	139	231
1984	76	165	241
1985	0	82	82
1986	7	0	7
1987	0	30	30
1988	524	0	524
1989	0	6986	6986
1990	1003	5730	6733
1991	75	2819	2894

* Private Carriage refers to rail car leasing companies and shippers. A C113 is a covered hopper car with gravity discharge unloading and a load capacity between 4000 and 5000 cubic feet.

Source: Jerry Norton and Keith Klindworth, Railcars for Grain, Future Need and Availability. U.S. Department of Agriculture, Office of Transportation, July 1989, p. 20.

THE MODEL

The model of C113 investment is based on Gould (1968) who incorporated adjustment costs into a profit maximizing firm's investment decision. Gould postulated that a representative firm will maximize cash flow (V), as defined in equation (1).

$$MAX\ V = \int_0^{\infty} e^{-rt}\,[P(t)Q - w(t)L(t) - C(I)]dt \qquad (1)$$

r - real interest rate at time t
P(t) - output price at time t
Q - output
w(t) - wage rate at time t
L(t) - labor input at time t
C(I) - costs associated with investment

With the assumption of a convex cost function, $C'(I) > 0$, $C''(I) > 0$, the optimal capital accumulation path is solved by using the calculus of variations. The desired long run net investment I^* is given in equation (2), where δ is the depreciation rate and K^* is desired capital stock.

$$I^* = \delta K^* \qquad (2)$$

$$I = \dot{K} + \delta K \qquad (3)$$

I - gross investment

$\dot{K}$ - rate of change in capital stock with respect to time

K - existing capital stock

The identity in (3) and equation (2) implies the adjustment path for capital stock given in (4).

$$\dot{K} = \delta(K^* - K) \qquad (4)$$

Given equation (4), equation (3) can be formulated as a distributed lag with declining weights.

The C113 investment model employed in this study is also predicated on Nerlove (1958) who developed a distributed lag model for product demand based on observable variables.

With the assumption of static expectations, equation (5) represents

$$q_t - q_{t-1} = \gamma[q^* - q_{t-1}],\ 0 < \gamma \leq 1 \qquad (5)$$

the relationship between current quantity demanded q_t, the lagged quantity demanded q_{t-1}, and q^*, the long run equilibrium value of quantity demanded. The parameter γ represents a fixed adjustment rate and as γ approaches 0, adjustments are rigid while as γ approaches 1, adjustments are instantaneous.

Since prices are continuously changing, q^* is unobservable. Theoretically, q^* is a function of the long run price elasticity, a, and long run income elasticity, b.

$$q^* = aP_t + bY_t + c \tag{6}$$

By substituting (6) into (5) we get an equation with observable variables.

$$q_t = \gamma aP_t + \gamma bY_t + (1 - \gamma)q_{t-1} + \gamma c \tag{7}$$

The lagged dependent variable's coefficient in equation (7) is the partial adjustment coefficient which shows the percentage adjustment made in quantity demanded in response to changes both in income and prices.

According to the Gould investment model, a representative Class I rail firm will maximize the cash flow from C113 investment as indicated in equation (8).

$$MAX\ V = \int_0^{\infty} e^{-rt} [FRGT(t)CARLOADS - PC113(t)C113(t) - C(I)]dt \tag{8}$$

r	- real interest rate at time t
FRGT(t)	- freight rate for grain per carload at time t
CARLOADS	- carloads of grain transported
PC113(t)	- price of a new C113 rail car at time t
C113(t)	- number of C113 rail cars acquired during time t
C(I)	- concave cost function associated with adjusting the existing C113 stock of rail cars.

A geometrically declining partial adjustment equation (equation 9) for C113 investment is imposed on the model.

$$C113_t - C113_{t-1} = \alpha(C113^* - C113_{t-1}) \tag{9}$$

$C113_t$	-	actual stock of C113 rail cars at time t
$C113_{t-1}$	-	stock of C113 rail cars, lagged one year
α	-	constant partial adjustment coefficient
C113*	-	desired stock of C113 rail cars

The partial adjustment coefficient, α, reveals the percentage of the required stock adjustment that can be completed in one year.

Based on Nerlove's model, a C113 investment model for Class I railroads is specified as follows:

$$C113 = \beta_0 + \beta_1 PC113 + \beta_2 FRGT + \beta_3 INTEREST + \beta_4 C113_{t-1} + \beta_5 TECH + \beta_6 TCAR \quad (10)$$

C113	-	annual additions of C113s by Class I railroads
PC113	-	C113 price in 1990 dollars
FRGT	-	freight rate per carload in 1990 dollars for commodities shipped in C113s
INTEREST	-	average annual yield of Moody's AAA corporate bonds in 1990 dollars
$C113_{t-1}$	-	annual additions of C113s by Class I railroads, lagged one year
TECH	-	dummy variable equal to 1.0 in 1980 and zero in other years
TCAR	-	average annual tons per carload of C113 commodities

Referring to equation (8), it can be shown that with the assumption of static expectations, C113 investment is expected to vary as follows:

$$\frac{\partial\ C113}{\partial\ INTEREST} < 0,\ \frac{\partial\ C113}{\partial\ PC113} < 0,\ \frac{\partial\ C113}{\partial\ FRGT} > 0$$

Due to rapidly increasing demand for export grain transportation and the shift to increased use of unit trains, railroads phased out the use of inefficient boxcars and replaced them with a very large investment in C113s in 1980. A case could be made that this technological shift also partly occurred in 1979 and 1981. However we feel that the potential increase in explanatory power is offset by the loss in degrees of freedom associated with adding 2 additional dummy variables. Also interviews with industry experts indicate that the large increase in C113 investment in 1980 was a one time episode to replace remaining boxcars with C113s (Harding Associates, 1993). The theoretically expected sign of the dummy variable TECH is positive.

For $C113_{t-1}$, the coefficient β_4 is expected to be between zero and one. The partial adjustment coefficient, α, is determined by subtracting β_4 from unity.

Average annual tons per carload of C113 commodities is included in the model to account for the substitution of larger capacity cars for smaller ones over time. As the capacity of the car fleet increases, investment in additional C113s should decrease since fewer large cars are required to transport the same amount of grain.

Although PC113 is determined by the interaction of C113 supply and demand, we assume that PC113 is exogenously determined. Simultaneity is avoided by only estimating the investment demand for C113s.

As noted above, C113s are also owned by rail car leasing companies and shippers (referred to as private carriage). It can be argued that rail car leasing company and shipper investment in C113s is determined by the same variables that affect Class I railroad investment. For example, all three groups would reduce investment in C113s in response to a higher C113 price and higher interest rates. To the extent that increasing rail grain prices reflects increased demand for grain transportation, all three groups would increase investment in C113s.

However, it can also be argued that shipper investment in C113s is affected by factors that are not in equation (10). For example, shippers may invest in C113s to ensure themselves of a supply of rail cars. This enables the shipper to achieve several service advantages such as increased convenience, flexibility, logistical control, less loss and damage, and lower transit times (i.e. shipper doesn't have to wait for the railroad to supply cars). Access to its own rail cars may also permit the shipper to reduce inventory carrying costs.

The above considerations indicate that a different model should be specified for shipper C113 investment. However there are at least two barriers to accomplishing this. First, it is extremely difficult, if not impossible, to quantify shipper convenience, flexibility, transit times, and inventory carrying costs. Second, the AAR does not compile separate C113 data for shippers but rather combines it with car leasing company data. However, given the arguments both for and against the applicability of equation (10) to shipper C113 investment, we estimate the model for Class I railroads, Private Carriage, and the combined total of both groups.

DATA

Fleet additions of C113s for 1964 to 1988 are from Norton and Klindworth (1989, p. 20). They obtained the data from the AAR's Uniform Machine Language Equipment Register (UMLER). The data for 1989-91 was furnished by the AAR Economics and Finance Department who obtained it from UMLER.

Annual C113 prices are proxied by annual covered hopper car prices recorded in the AAR's Yearbook of Railroad Facts (various issues). This is a proxy because it is likely that in years prior to 1980, the price measure is affected by non-C113 covered hopper cars. No price was listed for 1986, so a linear interpolation was performed between the years 1985 and 1987. Although this proxy for C113 prices is imprecise, no other data source is publicly available.

The Class I railroad freight rate per carload is proxied by Class I railroad revenue per carload. Both revenue and carloads are obtained from various issues of Freight Commodity Statistics published by the ICC until 1979 and by the AAR in subsequent years. Revenue per carload is the aggregate figure for the following grains:

Barley
Corn
Oats
Rough Rice
Rye
Sorghum
Soybeans (actually an oilseed)
Wheat
Other Grain

According to Norton and Klindworth (1989, p. 23), C113s are also employed by Class I railroads to haul non-grain commodities such as chemicals and grain mill products. Thus FRGT is a weighted average of revenue per carload that reflects rail prices of non-grain commodities as well as the grains listed above. Revenue and carloads for non-grain commodities are also obtained from Freight Commodity Statistics. The weights for computing the average are from Norton and Klindworth (1989, p. 23).

The interest rate selected is the average annual Moody's AAA corporate bond rate obtained from Economic Report of the President (1993, p. 428). Real interest rates are calculated using the method suggested in Casler et al (1984, p. 90)[1].

$$r = \left(\frac{1 + i}{1 + \pi}\right) - 1 \tag{11}$$

r	-	real interest rate
i	-	nominal interest rate
π	-	inflation rate

The deflator employed to calculate real INTEREST, PC113 and FRGT, is the railroad cost index published by the AAR in Yearbook of Railroad Facts. Other measures of inflation such as the Consumer Price Index (CPI) or the Producer Price Index (PPI) could also have been used as deflators. However, it is unlikely that the results are affected by the choice of deflator since the correlation coefficient between the CPI and the railroad cost index is greater than 0.90. The same is true for the PPI and the railroad cost index.

Annual tons per carload of C113 commodities (TCAR) is obtained by dividing the total tons of grain, grain products, and fertilizer by the total carloads of these products. Tons and carloads are from Freight Commodity Statistics.

EMPIRICAL RESULTS

Equation (10) cannot be estimated by OLS since it is an autoregressive model. These models have two problems that make OLS estimation inappropriate.[2] The first of these problems is the tendency of the lagged dependent variable to be correlated with the disturbance term. The second problem is the propensity for first order serial correlation of the error term.

The first of the above problems can be resolved through use of the instrumental variables technique. The key idea of this method is to replace the lagged dependent variable with another variable that is highly correlated with the lagged dependent variable but uncorrelated with the disturbance term. To obtain a proxy for the lagged dependent variable in equation (10) we first regressed the dependent variable on all the independent variables and the one period lagged values of the independent variables. Then, the fitted values of the dependent variable from the instrumental regression are lagged by one year and used in the estimation of equation (10).

When equation (10) is estimated with the instrumental variable the Durbin h statistic revealed the existence of first order serial correlation in the Class I railroad equation.[3] This problem is eliminated using the standard Cochrane-Orcutt procedure. The Private Carriage and Total equations do not have first order serial correlation.

The equations are estimated with annual data for the 1964-1991 period.

Table 2 contains the estimated C113 investment equations for Class I railroads, Private Carriage (shippers and car leasing companies), and the total of these two groups. In the Class I railroad equation, all of the independent variables have the theoretically expected sign. Independent variable TCAR is statistically significant at the .10 level, PC113 at the .05 level, while all the other explanatory variables are significant at the .01 level. The adjusted R^2 is 0.89 so the equation does a good job of explaining Class I railroad C113 investment. The partial adjustment coefficient is equal to one minus the coefficient of $C113_{t-1}$ or 0.51. This is interpreted to mean that about one half of the gap between the desired and actual stock of C113s is closed in one year.

In the Private Carriage equation, explanatory variables FRGT, INTEREST, and TECH have the theoretically expected sign and FRGT and TECH are statistically significant at the .05 level; INTEREST at the .10 level. However independent variables PC113, $C113_{t-1}$, and TCAR are not significant and TCAR has the wrong sign. Since the coefficient of $C113_{t-1}$ is non-significant, no confidence can be placed in the partial adjustment coefficient of 0.68. The fit of the equation is not particularly good with an adjusted R^2 of only 0.42. Thus the model in equation (10) does a good job of explaining Class I railroad C113 investment but it does a poor job of explaining Private Carriage C113 investment. This appears to indicate that private carriage and Class I railroads have different C113 investment motives.

In the Total equation, explanatory variables FRGT and TECH are statistically significant at the .01 level, INTEREST at the .05 level, and $C113_{t-1}$ is significant at the .10 level. All of these variables have the expected sign. Variables PC113 and TCAR are non-significant and TCAR has the wrong sign. The partial adjustment coefficient is 0.62 and the adjusted R^2 is 0.68.

Elasticities for the statistically significant variables in the Class I railroad, Private Carriage, and Total equations are displayed in Table 3. The long run mean elasticity for independent variable i and dependent variable x is calculated as follows:

$$\text{Long Run Elasticity}_i = (\text{Coefficient}_i)\ \left(\frac{Mean_i}{Mean_x}\right) \tag{12}$$

According to Griliches (1960), short run elasticities are the product of the partial adjustment coefficient (γ) and the long run elasticity as indicated in (13).

$$\text{Short Run Elasticity}_i = (\text{Long Run Elasticity})_i\ (\gamma) \tag{13}$$

In the short run, Class I railroad C113 investment is inelastic with respect to all the independent variables except FRGT, although TCAR is virtually unit elastic. No short run elasticities are listed for the Private Carriage equation because the partial adjustment coefficient is non-significant. Total C113 investment is elastic with respect to FRGT and INTEREST and inelastic with respect to $C113_{t-1}$.

Table 2

C113 Railcar Investment Regression Results

	Class I Railroads	Private Carriage	Total
Constant	10337.60 (1.72)**	-13668 (-0.98)	-3668.45 (-.21)
PC113	-.094 (-2.04)**	-0.0084 (-0.098)	-0.096 (-0.84)
FRGT	5.36 (3.04)*	8.06 (2.08)**	13.99 (2.72)*
INTEREST	-580.11 (-2.51)*	-937.39 (-1.92)***	-1501.34 (-2.24)**
$C113_{t-1}$	0.49 (2.90)*	0.32 (1.18)	0.38 (1.83)***
TCAR	-94.32 (-1.68)***	141.48 (1.13)	36.92 (0.23)
TECH	11546.50 (6.54)*	6796.25 (2.02)**	17394.80 (3.95)*
ADJUSTMENT COEFFICIENT	0.51	0.68	0.62
ADJUSTED R^2	0.89	0.42	0.68

t statistics appear in parentheses

*indicates significance at the 0.01 level
**indicates significance at the 0.05 level
***indicates significance at the 0.10 level

As expected, all the long run elasticities are higher than their corresponding short run elasticities. All the long run elasticities are greater than 1.0 except those for $C113_{t-1}$. The elasticities of the FRGT variable are larger than those of any other explanatory variable for all 3 equations and in both the long run and the short run.

The long run elasticities in Table 3 appear to indicate that Class I railroads and Private Carriage have different C113 investment motives and also respond differently to the same variables. For example, Private Carriage C113 investment doesn't respond to PC113, TCAR, or $C113_{t-1}$, whereas Class I railroad investment does respond to these variables and is elastic with respect to PC113 and TCAR in the long run. Class I railroad and Private Carriage C113 investment responds to FRGT and INTEREST. However the long run elasticities of these variables for Private Carriage are much higher than those of Class I railroads.

The adjustment path from the actual to the desired stock of C113s is assumed to be a distributed lag with geometrically declining weights. With this assumption, the first year's adjustment for the Class I railroad model is the partial adjustment coefficient, 0.51, or 51 percent (see Table 4). The second year's adjustment is the product of the partial adjustment coefficient (0.51) and the coefficient of $C113_{t-1}$ from the Class I railroad equation (0.49), or 25 percent. The third year's adjustment is $(0.51)\ (0.49)^2$ which is 12 percent and the fourth year's adjustment is $(0.51)\ (0.49)^3$ or 6 percent. The corresponding annual adjustments for the Total equation are 62, 24, 9, and 3 percent.

With geometrically declining weights, 100 percent adjustment of the actual capital stock to the desired stock is approached asymptotically (Gujarati, 1988, p. 521). Thus when total adjustment exceeds 90 percent we considered the adjustment of actual to desired C113s to be complete. This occurred after 4 years for the Class I railroad equation and after 3 years for the Total equation. No adjustment periods are calculated for the Private Carriage equation since the coefficient of $C113_{t-1}$ is statistically non-significant in that equation.

Does a 3 to 4 year lag seem reasonable? The principal commodity shipped in C113s is grain and the demand for grain transportation is unstable. Thus if the demand for grain transportation increases, railroads will postpone investment in additional C113s until they form the expectation that the increased demand is permanent. Conceivably this could require 2 to 3 years and coupled with a year for production of a car, a 3 to 4 year lag seems to be reasonable.

WHAT CAUSED THE 1980S INVESTMENT DEARTH?

Perhaps the most important cause of the C113 investment decline of the 1980s is the decline in rail prices for commodities hauled in C113s. Rail deregulation that intensified intramodal competition, coupled with declining export demand for U.S. grain, helped cause independent variable FRGT to decline from $2070.43 per carload in 1980 to $1283.25 in 1991, a 38 percent decline (see Appendix). Since FRGT has the largest long run elasticity of any explanatory variable, a 38 percent decline in its value explains much of the decline in C113 investment.

Table 3

Elasticities of C113 Railcar Investment Determinants

Equation	Independent Variable	Short Run Elasticity	Long Run Elasticity
	PC113		
Class I		-0.80	-1.57
Private Carriage		--	--
Total		--	--
	FRGT		
Class I		1.18	2.31
Private Carriage		--	4.21
Total		2.05	3.31
	INTEREST		
Class I		-0.63	-1.23
Private Carriage		--	-2.42
Total		-1.09	-1.75
	$C113_{t-1}$		
Class I		0.26	0.50
Private Carriage		--	--
Total		0.24	0.38
	TCAR		
Class I		-0.98	-1.92
Private Carriage		--	--
Total		--	--

- indicates statistical insignificance at .10 level

Although FRGT and INTEREST are statistically significant in the Private Carriage equation, the short run elasticities for these variables are not listed since they are obtained by multiplying the long run elasticity by the non-significant partial adjustment coefficient of the Private Carriage equation.

Table 4

C113 Railcar Investment Adjustment Period

Model	Year	Adjustment Per Year	Total Adjustment
	One		
Class I Railroad		51%	51%
Total		62%	62%
	Two		
Class I Railroad		51%(49%) = 25%	51% + 25% = 76%
Total		62% (38%) = 24%	62% + 24% = 86%
	Three		
Class I Railroad		$51\%(49\%)^2$ = 12%	76% + 12% = 88%
Total		$62\%(38\%)^2$ = 9%	86% + 9% = 95%
	Four		
Class I Railroad		$51\%(49\%)^3$ = 6%	88% + 6% = 94%
Total		$62\%(38\%)^3$ = 3%	95% + 3% = 98%

No data is presented for the Private Carriage equation since the coefficient of $C113_{t-1}$ is statistically non-significant in that equation.

Real interest rates (INTEREST) peaked in 1981 and trended downward through 1991 (see Appendix). However it is likely that interest rates had a negative impact on C113 investment since real interest rates were high in the 1981-91 period by historical standards. For example the average annual real interest rate during the 1964-80 period was 6.22 percent compared to 9.33 percent for the 1981-91 interval.

Explanatory variables FRGT and INTEREST affected 1980s C113 investment of both Class I railroads and private carriage. Other variables such as TCAR had an impact only on

Class I railroad investment. Between 1964 and 1991 TCAR approximately doubled from 46.1 to 90.09, with the increase occurring in a nearly uninterrupted upward trend (see Appendix). Thus it is likely that TCAR had as great a negative impact on Class I railroad C113 investment in the 1980s as it did prior to 1980.

Real C113 price is another variable that has affected Class I railroad C113 investment. As noted previously, real C113 price has the theoretically expected inverse relationship to C113 investment. Between 1983 and 1987, PC113 plunged from $79,109 to $38,222, a 52 percent decline (see Appendix). Real C113 price recovered somewhat in the 1988-91 period but remained low. Thus the low PC113 prices should have stimulated Class I railroad C113 investment. Possibly the positive impact on C113 investment of lower PC113 was overwhelmed by the negative effects of declining freight rates and increasing tons per carload. The long run elasticities in Table 3 lend credence to this scenario since the elasticities of FRGT (2.31) and TCAR (-1.92) exceed the elasticity of PC113 (-1.57).

We did not include railroad use of unit trains (shipments of at least 50 cars) in our model due to data constraints. However, according to MacDonald (1989, pp. 15-19) railroads substantially increased the use of unit trains to ship grain following rail deregulation in 1980. Since unit trains increase the productivity of C113s, the shift to unit trains probably had a negative effect on C113 investment.

CONCLUSION

The principal conclusions of this paper are as follows:

1. The partial adjustment autoregressive model of this study does a good job of explaining Class I railroad C113 investment during the 1964-91 period.
2. The partial adjustment autoregressive model of this study does a poor job of explaining Private Carriage C113 investment during the 1964-91 period.
3. While Class I railroad and Private Carriage C113 investment responds to some of the same factors, they also appear to have different investment motives.
4. During the 1964-91 period, Class I railroad C113 investment is inversely related to the real price of C113s, real interest rates, and C113 tons per carload. It is directly related to real railroad price per carload of C113 commodities; C113 acquisitions, lagged one year; and a technological change dummy variable.
5. In the short run (one year), Class I railroad C113 investment is inelastic with respect to every explanatory variable except FRGT. In the long run (4 years), it is elastic with respect to every explanatory variable except $C113_{t-1}$. The explanatory variable FRGT has the highest elasticity in both the short run and long run.
6. For Class I railroad C113 investment, approximately four years are required to eliminate the gap between the actual and desired stock of C113s. In the first year, 51 percent of the gap is closed, followed by 76 percent, 88 percent, and 94 percent in the succeeding years.

7. The decline in C113 investment during the 1980s was partly caused by a decline in the real railroad price per carload of C113 commodities, high real interest rate levels, and increasing average tons per carload of C113 commodities.

Hopefully this study brings some rationality to the often emotional debate regarding the adequacy of the nation's grain railcar fleet. All parties to the debate need to recognize that railroads base their car investment decisions on an assessment of the costs and potential revenues of the investment. When economic conditions are favorable, profit driven railroads will increase investment in railcars but the adjustment takes time. This is useful information for the ICC since it suggests that the ICC consider the effect of their grain price and car allocation decisions on railroad C113 investment determinants. Shippers need to realize that profit driven railroads will not supply all the railcars they desire and that other transportation-logistical options need to be explored. This study sheds light on the economics of railcar investment, and given the results, perhaps the railroads and shippers won't have to keep saying to each other, "but you don't understand my problem!"

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ENDNOTES

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1. The expression for the real interest rate in equation (11) is based on the following financial identity.

$$1 + i = (1 + r)(1 + \pi)$$

i - nominal interest rate
r - real interest rate
π - inflation rate

From the above identity, equation (11) can be easily derived as follows:

$$(1 + r) = \frac{(1 + i)}{(1 + \pi)}$$

$$r = \frac{(1 + i)}{(1 + \pi)} - 1$$

2. See Gujarati (1988), p. 523.

3. The Durbin-Watson d statistic may not be used to detect first order serial correlation in autoregressive models because the computed d value in such models generally tends toward 2.0 which is the value of d when there is no serial correlation. Thus relying on d results in a built-in bias against discovering first order serial correlation. Therefore Durbin's h statistic must be used to test for serial correlation in autoregressive models. See Gujarati (1988), p. 526.

APPENDIX

Independent Variable Data
1964-1991

Year	INTEREST[1]	FRGT[2]	TCAR[3]	TECH[4]	PC113[5]
1964	3.20%	$1654.12	46.11	0	$97280.00
1965	3.40	1565.21	51.25	0	91137.50
1966	4.00	1558.53	53.79	0	93295.11
1967	4.40	1485.14	53.90	0	85163.91
1968	5.06	1494.73	57.82	0	78340.31
1969	6.50	1469.33	58.84	0	75482.44
1970	6.86	1576.29	60.94	0	74408.30
1971	6.23	1628.20	62.72	0	68443.09
1972	6.05	1432.91	62.28	0	70073.61
1973	6.25	1651.93	66.05	0	62068.97
1974	7.35	1852.65	68.48	0	60422.96
1975	7.60	1606.76	71.54	0	70238.73
1976	7.30	1621.69	71.92	0	65739.22
1977	6.90	1802.72	74.72	0	63013.27
1978	7.52	1980.77	76.45	0	66835.70
1979	8.41	1963.27	77.00	0	65935.59
1980	10.60	2070.43	80.98	1	68798.10
1981	12.80	1966.60	83.82	0	58545.45
1982	12.59	1778.47	86.00	0	79108.78
1983	10.89	1520.92	87.58	0	46902.00
1984	11.56	1550.77	88.72	0	35917.38
1985	10.55	1443.43	89.14	0	39803.35
1986	7.92	1380.62	92.47	0	39012.53
1987	8.25	1263.98	88.46	0	38221.71
1988	8.57	1344.77	90.26	0	44404.60
1989	8.14	1322.31	90.67	0	47268.91
1990	8.18	1244.18	90.08	0	45000.00
1991	7.58	1283.25	90.90	0	42500.00

[1]Real average annual Moody's AAA Yield
[2]Real average annual freight rates ($/carload), 1990 dollars
[3]Average tons per carload of C113 commodities
[4]Technology dummy variable
[5]Real C113 price, 1990 dollars