Revisiting Engel's Law: Examining Expenditure Patterns for Food at Home and Away From Home

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Expenditure patterns were examined for food partitioned into food at home and away from home to test the veracity of Engel's law. The analysis employed serveral functional forms and a Heckman two-step methodology to account for censored-response bias. Engel's law was verified in every case.

In 1857, Ernst Engel produced arguably the most famous statistical analysis of household budgets to date. In this document, Engel presented a fundamental principle which today we know as Engel's law; poorer households devote a higher share of income to food than richer households. The same is true of larger households over smaller households, given an equal level of income (Deaton and Muellbauer). There are few assertions in economics that can be rightfully called a law. Houthakker (1987) commented that, "Of all empirical regularities observed in economic data, Engel's law is probably the best established."

Engel's work founded what was to become an essential branch of econometrics. Even so, in the years to follow 1857, research devoted to consumption analysis did little to expand upon Engel's law. It was well into the 20th century when empirical work in the economics of consumer behavior gained a sound theoretical base (Stigler). Indebted to this empirical heritage, Houthakker (1957) revisited Engel's analysis in a centennial celebration of Engel's law. Houthakker's work examined numerous international household surveys, confirming Engel's law in every case.

Since Houthakker's seminal publication, we have observed noticeable trends in U.S. household food expenditures. In 1992, U.S. households spent 45% of their food dollar on food away from home (FAFH), up from 39% in 1980 and 34% in 1970 (Manchester). This trend is expected to continue into the 21st century, with expenditures on FAFH growing at a faster rate than expenditures on food at home (FAH) (Blisard and Blaylock).

According to Senauer, Asp, and Kinsey (p.13), "rapid changes have occurred in the way food is prepared, in who cooks it, and in the places it is consumed." Fundamental changes are occurring in purchasing patterns of the typical U.S. household. In light of these changes, it becomes pertinent once again to examine Engel's law. Also, confirmation of Engel's law for total food expenditures in no way implies the same result will be found when food expenditures are partitioned into FAFH and FAH. Plots of the data in Figures 1, 2, and 3 illustrate a possible Engel relationship for total food, FAFH, and FAH. On inspection one may accept Engel's law out of hand. The objective of this paper is simply to examine the veracity of Engel's law applied to expenditures on both FAH and FAFH. In this respect, this paper is a pedagogical note.

Data

The data set used for this analysis was the 1987-88 Nationwide Food Consumption Survey (NFCS), targeted at all private households in the adjoining 48 states. Although designed to provide a sample of 6,000 households, only 4,495 households returned completed interviews. These households provided records on the monetary values, quantities, and types of food purchased over a one-week period. Various sociodemographic characteristics of the households, including household size and income, were also reported. This analysis used only housekeeping

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Figure 1: Scatter Plot of Weekly Income and Total Food Budget Share.

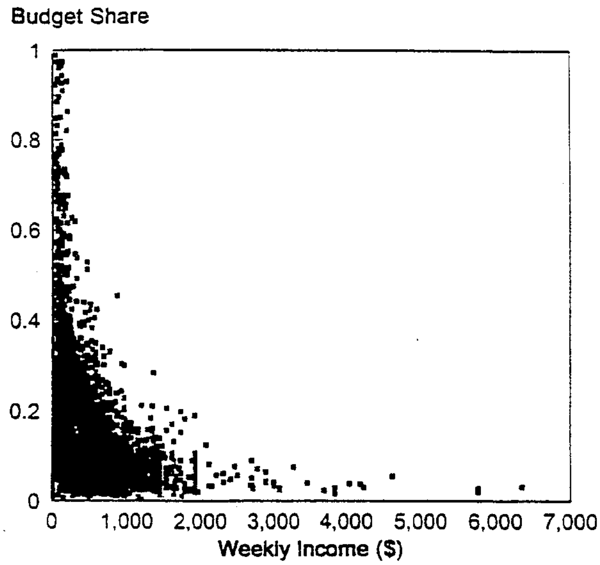


Figure 2: Scatter Plot of Weekly Income and FAFH Budget Share.

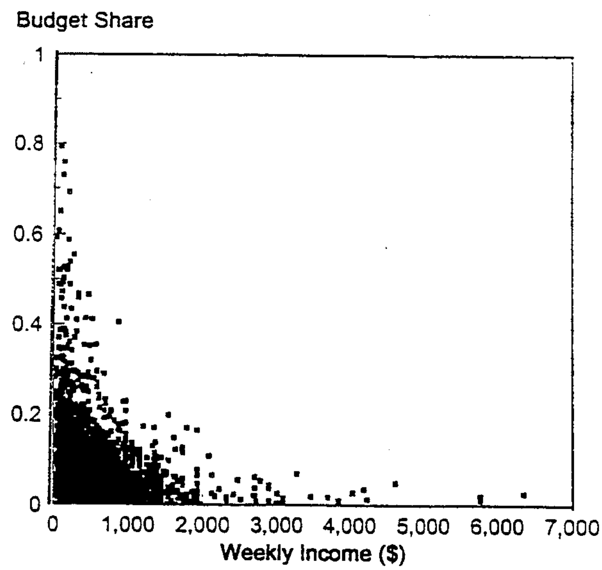
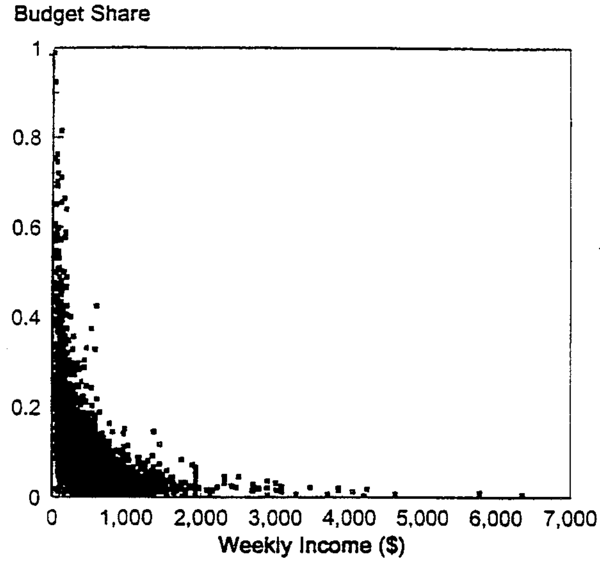


Figure 3: Scatter Plot of Weeky Income and FAH Budget Share.



households, i.e. at least one person ate ten or more meals from the household food supply during the seven-day survey period.

Food expenditures were divided into twelve groups: FAFH, beef, pork, chicken, fish, cheese, milk, fruits, vegetables, breakfast cereals, bread, and fats and oils. The summation of expenditures on all groups except FAFH was defined as FAH. Total food was defined as the summation of FAFH and FAH. Weekly budget shares for food were developed by dividing food expenditures (Total Food, FAFH, and FAH) by weekly income, which was generated by dividing annual before-tax household income by 52. In order for budget shares to be confined in the interval between zero and one, households that reported having either no annual income or a resulting weekly income less than their reported weekly food expenditures were not used. Also, only White, Black, and Asian/Pacific Islander households were analyzed, leaving a total of 3,842 observations for estimation purposes. The data suggest that on average, households devoted approximately 15% of their income to Total Food expenditures. Approximately 9% of household income was devoted to FAH and 6% to FAFH (Table1).

Table 1: Descriptive statistics.

Variable	Mean	Std Dev	Min	Max
	Weekly Food Expenditures ($)			
FAFH	27.19	33.36	0.00	350.00
FAH	31.98	20.86	1.00	253.00
FOOD	59.17	42.62	1.00	393.00
	Weekly Food Budget Shares			
FAFHS	0.0581	0.0755	0.0000	0.7930
FAHS	0.0947	0.0969	0.0015	0.9896
FOODS	0.1528	0.1313	0.0017	0.9896
	Household Size and Weekly Income ($)			
HSIZE	2.70	1.41	1.00	12.00
WEEKINC	539.86	458.10	11.12	6351.90

Procedure

Every household used in this analysis purchased items from at least one of the eleven groups included in the FAH category during the survey week. Therefore, no household submitted a zero expenditure for Total Food or FAH. However, not all households purchased FAFH, resulting in FAFH budget share values of zero. The two-step procedure of Heckman was used to circumvent this censored-response problem, as this procedure is less restrictive than the Tobit estimation technique (Haines et al.). As an alternative to the Heckman procedure one could use the switching regression technique of Lee and Brown. Because of computational ease, we chose the Heckman procedure over the switching regression analysis. Importantly too, both techniques yield consistent parameter estimates.

The first statge of the Heckman procedure consisted of using a probit analysis to generate the inverse Mills ratio (MR_h) for the h^{th} household's expenditure on FAFH. The second stage is appropriately estimated by either ordinary or generalized least squares. GLS is the preferred technique in the presence of heteroskedasticity, however its implementation is not always possible (Heckman). The inverse Mills ration was used as an explanatory variable in the second-stage estimation to incorporate the censoring latent variable in the regression. Only the non-zero observations were used in the second step. Mathematically, the procedure is denoted:

$$(1)\quad Pr[Z_h = 1] = \Phi(W_h\delta) \quad h = 1,\ldots,H$$

where:

$$Z_h = \begin{Bmatrix} 1 & if\, FAFH > 0 \\ 0 & otherwise \end{Bmatrix}$$

where Z_h is the binary dependent variable, Φ is the standard normal cumulative distribution function, W_h is a vector of regressors related to the purchase decision, and δ is the coefficient vector associated with the regressors. The inverse Mills ratio generated by the probit analysis is described as:

$$(2)\quad \widehat{MR}_h = \left\{ \frac{\phi(W_h\hat{\delta})}{\Phi(W_h\hat{\delta})} \text{ for } Z_h = 1 \right\}$$

where ϕ is the standard normal probability density function.

Functional Form

Historically in examination of Engel's law, the functional form used has been the double-logarithmic form (linear in logarithms). Interestingly, Engel used a double-logarithmic approximation in his paper of 1857 (pp. 30-31). The reason for this selection was that the verification of Engel's law rested on the magnitude of the income elasticity. Engel's law, strictly speaking, refers to income elasticities. If Engel's law holds, then it can be shown that the income elasticity for that commodity must be less than one. The proof of this contention is as follows: let w represent the budget share for food and let y represent income. Note that $w=pq/y$, where p is the price of food and q is the quantity of food, respectively. According to Engel's law, $\partial w/\partial y < 0$. But, $\partial w/\partial y = (p/y)(\partial q/\partial y) - (w/y)$. Then $p(\partial q/\partial y) < w$ under the condition that $\partial w/\partial y < 0$. Hence, $\eta < 1$, where η is the income elasticity.

The double-logarithmic form provides the estimate of the income elasticity directly. The down side of the use of this functional form is that this elasticity is constant over all households. This feature may be too restrictive. Also, the double-logarithmic form is unable to consider zero values in the dependent variable. Prais and Houthakker recommended the semi-logarithmic function, especially for necessities such as food.

In addition, a quadratic functional form also is commonly used in such analyses.

A less common alternative is the Working-Leser empirical form. The basic premise of this model is the relation of value shares to the logarithm of income or total expenditures. Therefore, the regression of food budget shares on the logarithm of weekly income allows a direct test of Engel's law. This functional form permits non-linear Engel curves, a vital feature when analyzing the budget share-income relationship over a large range of incomes (Prais). Also, non-linear Engel curves provide determination of a good as a luxury or a necessity over the range of incomes (Prais; Prais and Houthakker). Thus, the Working-Leser form provides a "frontal attack" in the examination of Engel's law in that the dependent variable is in terms of the budget share. In contrast, dependent variables employed using more traditional functional forms historically have been expressed as expenditures.

Our analysis represents a contribution to the literature in three ways: (1) we examine Engel's law not only for total food, but also for FAH and for FAFH; (2) we employ the Working-Leser functional form in addition to more traditional forms, namely, the double-logarithmic, semi-logarithmic, and quadratic functional forms; and (3) we handle the censored-response problem in considering FAFH using the Heckman two-step technique.

Because a censored response is only a concerrn in the consumption of FAFH, only analyses of FAFH require the use of the inverse Mills ratio. Thus, the food categories were examined as three single-equation regressions for each of four functional forms: Working-Leser; double-logarithmic; semi-logarithmic; and quadratic. The mathematical forms of these estimated equations were as follows:

Working-Leser:

$$(3)\quad S_{hi} = a_{1i} + a_{2i}LWEEKINC_h + a_{3i}LHSIZE_h + a_{4i}NE_h + a_{5i}MW_h + a_{6i}WEST_h + a_{7i}CC_h + a_{8i}SUB_h + a_{9i}BLACK_h + a_{10i}ASIAN_h \{ + \alpha MR_h \} + \varepsilon_h$$

Semi-Logarithmic:

$$(4)\quad EXP_{hi} = b_{1i} + b_{2i}LWEEKINC_h + b_{3i}LHSIZE_h + b_{4i}NE_h + b_{5i}MW_h + b_{6i}WEST_h + b_{7i}CC_h + b_{8i}SUB_h + b_{9i}BLACK_h + b_{10i}ASIAN_h \{ + \beta MR_h \} + \varepsilon_h$$

Double-Logarithmic:

$$(5)\quad LEXP_{hi} = c_{1i} + c_{2i}LWEEKINC_h + c_{3i}LHSIZE_h + c_{4i}NE_h + c_{5i}MW_h + c_{6i}WEST_h + c_{7i}CC_h + c_{8i}SUB_h + c_{9i}BLACK_h + c_{10i}ASIAN_h \{ + \gamma MR_h \} + \varepsilon_h$$

Quadratic:

$$(6)\quad EXP_{hi} = d_{1i} + d_{2i}WEEKINC_h + d_{3i}HSIZE_h + d_{4i}WEEKINC_h^2 + d_{5i}HSIZE_h^2 + d_{6i}INC{*}HSIZE_h + d_{7i}NE_h + d_{8i}MW_h + d_{9i}WEST_h + d_{10i}CC_h + d_{11i}SUB_h + d_{12i}BLACK_h + d_{13i}ASIAN_h \{ + \delta MR_h \} + \varepsilon_h$$

where:

S_{hi}	=	expenditure share for the i^{th} food grouping and the h^{th} household; thus, share could be for Total Food (FOODS), FAFH (FAFHS), or FAH (FAHS).
EXP_{hi}	=	expenditure in dollars for the i^{th} food grouping and the h^{th} household.
$LEXP_{hi}$	=	logarithm of expenditure for the i^{th} food grouping and the h^{th} household.
$WEEKINC_h$	=	weekly income of household h.
$LWEEKINC_h$	=	logarithm of weekly income of household h.
$HSIZE_h$	=	household size of household h.
$LHSIZE_h$	=	logarithm of household size of household h.
$INC*HSIZE_h$	=	the interaction term of weekly income and household size in household h.
NE	=	binary variable representing a household in the Northeast region.
MW	=	binary variable representing a household in the Midwest region.
WEST	=	binary variable representing a household in the Western region.
CC	=	binary variable representing a household located in a Central City area.
SUB	=	binary variable representing a household located in a Suburban area.
BLACK	=	binary variable representing African-American household members.
ASIAN	=	binary variable representing Asian or Pacific Islander household members.
MR	=	inverse of Mills ratio used only in analysis of FAFH.

i food grouping; $i = 1,\ldots,3$
h surveyed household; $h = 1,\ldots, 3{,}842$

The possibility of heteroskedasticity in the data was examined. In the case of the Heckman two-step estimations (i.e. those employed for FAFH), heteroskedasticity was present in every case. From the Heckman procedure, we know the exact form of the heteroskedasticity. Thus, a precise correction can be made using GLS. This estimation is not always possible, however, as the process has the possibility of breaking down (see Heckman; Cheng and Capps). Such was the case in the FAFH estimations for each of the functional forms. Thus, FAFH equations were estimated by OLS without correcting for heteroskedasticity. In the case of the OLS regressions, we employ a Breusch-Pagan test. Heteroskedasticity was evident in every case, and corrections for heteroskedasticity were made accordingly. The parameters reported in these instances are the results of GLS regressions.

Results

The Working-Leser structure reported negative and stastistically significant parameter estimates for the logarithm of weekly income for Total Food, FAFH, and FAH (Table 2). The semi- and double-logarithmic forms reported positive and statistically significant parameter estimates for the logarithm of weekly income in all instances (Tables 3 and 4, respectively). All three of these functional forms reported positive and statistically significant coefficients for the logarithm of household size. For all three expenditure groups, the quadratic form reported positive and statistically significant coefficients for weekly income and household size, and negative and statistically significant coefficients for the squares of these two terms; the coefficients associated with the interaction term between income and house-

Table 2: Working-Leser Parameter Estimates.

Endogenous Variables	Equation Total Food	FAFH	FAH
LWEEKINC	-0.0768	-0.0499	-0.0721
	(-28.02)	(-9.34)	(-51.76)
LHSIZE	0.0367	0.0030	0.0502
	(16.00)	(0.50)	(42.90)
NE	0.0106	0.0015	-0.0003
	(4.15)	(0.38)	(-0.27)
MW	-0.0247	-0.0136	-0.0078
	(-10.25)	(-3.77)	(-6.64)
WEST	-0.0038	-0.0052	-0.00004
	(-1.50)	(-1.35)	(-0.03)
CC	0.0138	0.0110	0.0074
	(4.20)	(2.86)	(5.12)
SUB	-0.0265	0.0030	0.0030
	(-11.56)	(0.85)	(3.00)
BLACK	-0.0045	0.0052	0.0168
	(-0.76)	(1.00)	(5.83)
ASIAN	0.0253	-0.0192	0.0041
	(2.83)	(-1.36)	(0.83)
MR	--	-0.0674	--
		(-2.31)	
CONSTANT	0.5930	0.3930	0.4721
	(35.78)	(8.60)	(56.36)
R^2	0.4100	0.1362	0.5171

Note: t-statistics are in parentheses.

Table 3: Semi-Logarithmic parameter estimates.

Endogenous Variables	Equation Total Food	FAFH	FAH
LWEEKINC	15.7040	13.754	3.5359
	(28.84)	(5.99)	(12.18)
LHSIZE	23.6560	1.3710	16.8890
	(38.28)	(0.54)	(39.20)
NE	2.3294	1.2874	2.5282
	(2.12)	(0.78)	(4.16)
MW	-3.9360	-5.4025	-0.4780
	(-4.12)	(-3.48)	(-0.98)
WEST	-0.1320	-2.3607	-0.3718
	(-0.11)	(-1.41)	(-0.75)
CC	2.7123	5.0158	-0.8966
	(3.15)	(3.04)	(-1.80)
SUB	6.6408	1.5285	0.1122
	(7.47)	(1.00)	(0.24)
BLACK	2.0365	0.5009	2.1793
	(2.24)	(0.22)	(1.85)
ASIAN	0.8570	-5.4829	8.7215
	(0.15)	(-0.90)	(1.88)
MR	----	-15.06	----
		(-1.20)	
CONSTANT	-59.0440	-48.071	-4.2427
	(-21.73)	(-2.45)	(-2.84)
R^2	0.3554	0.1661	0.3381

Note: t-statistics are in parentheses.

hold size were statistically insignificant for the three expenditure groups (Table 5). The signs and significance of the estimated coefficients associated with the socio-demographic terms varied by expenditure group and functional form.

All empirical forms used in this study reported income elasticities of less than one for each expenditure group analyzed, verifying Engel's law in every case. The Working-Leser form verified Engel's law in two ways: directly by reporting negative and statistically significant coefficients for the logarithm of weekly income and indirectly by the calculated income elasticities. The semi-logarithmic form verified Engel's law for all three groups, but the characteristic of this functional form that the marginal propensity to consume (MPC) varies inversely with income may be too restrictive. The double-logarithmic form similarly supported Engel's law for Total Food and FAH, but the characteristic of constant income elasticities over a wide range of incomes may also be too restrictive.

For total food expenditures, income elasticities ranged from 0.2654 (semi-logarithmic) to 0.4975 (Working-Leser); household size elasticities varied from 0.2400 (Working-Leser) to 0.5659 (quadratic). For FAH, income elasticities ranged from 0.1105 (semi-logarithmic) to 0.2387 (Working-Leser); household size elasticities varied from 0.5281 (semi-logarithmic) to 0.6953 (quadratic). Finally, for FAFH, income elasticities ranged from 0.2999 (Working-Leser) to 0.6348 (quadratic); household size elasticities varied from 0.0411 (semi-logarithmic) to 0.1973 (quadratic). Conforming to expectations, FAFH was more affected by income than FAH. This result is consistent with findings by Houthakker and Taylor and by McCracken and Brandt. Household size elasticities were all positive, with FAH, as opposed to FAFH, exhibiting the larger elasticities (Table 6).

Table 4: Double-Logarithmic parameter estimates.

Endogenous Variables	Equation: Total Food	FAFH	FAH
LWEEKINC	0.3697	0.4843	0.1418
	(30.89)	(6.94)	(12.33)
LHSIZE	0.5562	0.1435	0.6782
	(32.48)	(1.86)	(44.05)
NE	0.0559	-0.0149	0.0925
	(2.29)	(-0.30)	(3.84)
MW	-0.0612	-0.1657	-0.0347
	(-2.75)	(-3.51)	(-1.58)
WEST	-0.0263	-0.1125	-0.0072
	(-1.01)	(-2.22)	(-0.31)
CC	0.0065	0.0786	-0.0279
	(0.25)	(1.57)	(-1.14)
SUB	0.0272	0.0140	0.0079
	(1.36)	(0.30)	(0.41)
BLACK	0.0212	0.0466	0.0343
	(0.72)	(0.69)	(1.14)
ASIAN	0.0539	-0.4238	0.2469
	(0.67)	(-2.30)	(3.33)
MR	--	-0.4581	--
		(-1.20)	
CONSTANT	1.1309	0.1058	1.8111
	(16.51)	(0.18)	(27.48)
R^2	0.4856	0.2132	0.4239

Note: t-statistics are in parentheses.

Table 5: Quadratic parameter estimates.

Endogenous Variables	Equation: Total Food	FAFH	FAH
WEEKINC	0.0497	0.0499	0.0088
	(11.89)	(5.79)	(5.04)
HSIZE	20.9640	7.0298	11.4550
	(22.19)	(3.02)	(16.79)
$WEEKINC^2$	-0.00001	-0.41E-5	-0.000002
	(-4.96)	(-3.71)	(-5.29)
$HSIZE^2$	-1.6877	-0.4811	-0.6926
	(-9.58)	(-2.31)	(-5.78)
INC*HSIZE	0.0010	-0.0033	0.0010
	(0.72)	(-2.67)	(1.59)
NE	-4.8327	0.6221	2.0077
	(-6.48)	(0.38)	(2.74)
MW	-4.6768	-4.4803	-1.7448
	(-6.38)	(-2.91)	(-3.60)
WEST	0.8632	-2.1351	-0.7014
	(1.00)	(-1.29)	(-1.20)
CC	2.4286	4.2439	-0.5721
	(2.10)	(2.60)	(-1.24)
SUB	2.4508	1.9495	0.7532
	(3.67)	(1.29)	(1.80)
BLACK	-1.2772	-2.7115	1.5582
	(-0.80)	(-1.15)	(1.19)
ASIAN	-1.7875	-5.6370	8.7497
	(-0.26)	(-0.94)	(1.79)
MR	--	5.1729	--
		(0.41)	
CONSTANT	-6.8691	-4.6488	1.6461
	(-5.75)	(-0.41)	(2.45)
R^2	0.3776	0.1885	0.3482

Note: t-statistics are in parentheses.

Table 6: Income and Household Size Elasticities at the means of the data.

Elasticity	Category		
	Total Food	FAFH	FAH
Working-Leser functional form			
Income	0.4975	0.2999	0.2387
Household Size	0.2400	0.0417	0.5296
Semi-Logarithmic functional form			
Income	0.2654	0.4120	0.1105
Household Size	0.3998	0.0411	0.5281
Double-Logarithmic functional form			
Income	0.3697	0.4843	0.1418
Household Size	0.5562	0.1435	0.6782
Quadratic functional form			
Income	0.4214	0.6348	0.1636
Household Size	0.5659	0.1973	0.6953

Conclusions

Using the 1987-88 NFCS data for U.S. households, Engel's law was verified once again. However, Engel's law was extended beyond total food expenditures to also include expenditures on both FAFH and FAH. Several functional forms were employed in this study: the Working-Leser; semi-logarithmic; double-logarithmic; and the quadratic forms. The Heckman two-step procedure was used to account for censored responses in the analysis of FAFH. Regardless of functional form, the results in robust fashion, verified Engel's law for Total Food, FAFH, and FAH. Thus, despite the changes in food consumption patterns over the past several decades, the venerable law of Engel still is very much in evidence.

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