Cyclicality, Mortality, and the Value of Time: The Case of Coffee Price Fluctuations and Child Survival in Colombia

Grant Miller

Stanford University and National Bureau of Economic Research

B. Piedad Urdinola

Universidad Nacional de Colombia

Recent studies demonstrate procyclical mortality in wealthy countries, but there are reasons to expect a countercyclical relationship in developing nations. We investigate how child survival in Colombia responds to fluctuations in world arabica coffee prices and document starkly procyclical child deaths. In studying this result's behavioral underpinnings, we highlight that (1) the leading determinants of child health are inexpensive but require considerable time, and (2) as the value of time declines with falling coffee prices, so does the relative price of health. We find a variety of direct evidence consistent with the primacy of time in child health production.

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I. Introduction

Prominent economic studies published in the past decade document procyclical mortality in the United States and other wealthy nations (Ruhm 2000, 2005, 2006; Dehejia and Lleras-Muney 2004; Neumayer 2004; Tapia Granados 2005).[1] In developing countries, however, there are reasons to expect the opposite relationship. Credit constraints and other market imperfections lead to incomplete consumption smoothing, potentially making health vulnerable to economic downturns (Sen 1981; Behrman and Deolalikar 1988; Sen and Drèze 1989). Caloric intake and dietary quality may deteriorate as a consequence, and the use of important health services may fall.

Casual empirical observation in Colombia does not match this expectation. For example, figures 1*A* and 1*B* show a distinctly procyclical relationship between the aggregate unemployment rate and detrended infant and child mortality rates.[2] Previous developing country studies are remarkably mixed, reporting both procyclical and countercyclical deaths alike as well as acyclical patterns of health.[3] These differences could partly be due to variation in methodologies for disentangling the complex interrelationship between economic conditions and mortality. Importantly, such heterogeneity may also be explained by the variety of different behavioral mechanisms implicated by homogeneously termed "macroeconomic shocks."[4]

To address the endogeneity of economic cycles (and to focus on one key behavioral mechanism), we investigate how infant and child survival in Colombia respond to abrupt changes in world arabica coffee prices. Colombia is the world's leading producer of washed arabica coffee beans (second only to Brazil in total coffee production), and as Colombia's principal export throughout much of the twentieth century, coffee plays an important macroeconomic role (Palacios 1980; Vinod 1985; Cárdenas

[1] Explanations proposed for this phenomenon emphasize that economic downturns moderate the consumption of harmful normal goods (such as alcohol and tobacco), decrease pollutant emissions, lower traffic fatality rates, and reduce the opportunity cost of time.

[2] Electronic Colombian vital records are available back to 1979; infant and child mortality rates are regression adjusted using a linear year variable.

[3] Cutler et al. (2002), Paxson and Schady (2005), van den Berg, Lindeboom, and Portrait (2006), Baird, Friedman, and Schady (2007), and Bhalotra (forthcoming) find countercyclical mortality; Ogburn and Thomas (1922), Thomas (1927), Ortega and Reher (1997), Abdala, Geldstein, and Mychaszula (2000), Fishback, Haines, and Kantor (2005), and Schady and Smitz (2009) report procyclical mortality; and Palloni and Hill (1997), Frankenberg, Thomas, and Beegle (1999), and Banerjee et al. (forthcoming) document acyclical health.

[4] In short, studies of different macroeconomic shocks may actually analyze different phenomena. For example, heavy rainfall and flooding destroy crops but also influence sanitary conditions and the reproduction of mosquito vectors responsible for disease transmission; financial crises often undermine public-sector health programs.

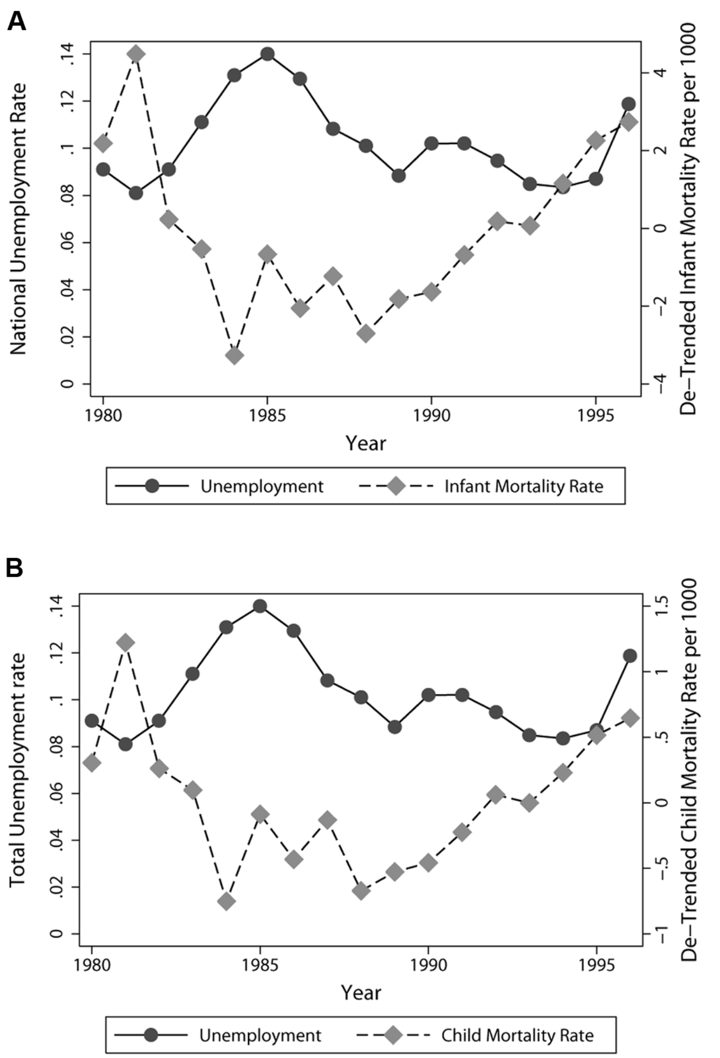

Fig. 1.—*A*, Colombian unemployment and detrended infant mortality rates, 1980–96. *B*, Colombian unemployment and detrended child (1–4) mortality rates, 1980–96.

1994; Uribe 2000; CEDE 2002).[5] Because of Colombia's prominence on world markets, we examine three external events that caused abrupt

[5] According to the Colombian national statistical agency, the share of GDP linked to coffee exceeds 20 percent in some Colombian departments, and coffee cultivation is the principal economic activity in many counties in Colombia's central coffee region (*zona cafetera*).

changes in world coffee prices: frosts that destroyed a large share of Brazilian coffee groves in 1975, the Brazilian drought of 1985, and the 1989–90 collapse of the International Coffee Agreement (governing cartel-like behavior among coffee-producing nations). Because price shocks occurred in both directions, we are able to study both booms and crashes (Meyer 1995).

Given the shortcomings of developing country vital registries, we also employ a novel measure of survival (or cumulative mortality): cohort size (Jayachandran 2009). Inferring mortality from cohort size offers several distinct advantages over other measures. These include freedom from underreporting, coverage of fetal deaths, and the ability to capture lagged mortality.[6]

Overall, we find a stark pattern of countercyclical cohort size. For a county with median coffee cultivation, a 25 percent birth year price increase (decrease) is accompanied by a 0.4–2.0 percent decrease (increase) in cohort size.[7] Because we measure cohort size by place of birth rather than by place of residence, migration is unlikely to play a role in explaining this result. We also restrict our analyses of each price shock to cohorts conceived before a shock occurred, minimizing the influence of fertility. If we attribute our estimates to mortality, implied procyclical changes in deaths under age 5 are approximately 15 percent.

We then seek to understand the behavioral foundations underlying these results. In doing so, we highlight that for institutional reasons, coffee price fluctuations in Colombia implicate one primary behavioral factor: the return to working (or the opportunity cost of time). Time is a critical health input, so all else equal, the relative price of health falls with the return to working (Grossman 1972; Gronau 1977; Rosenzweig and Schultz 1983; Mwabu 1988; Vistnes and Hamilton 1995). This is especially true for child health in developing countries: the most important determinants of child health are inexpensive but require large amounts of time (e.g., bringing pure water from distant sources, practicing good hygiene, and traveling to distant facilities for free preventive and primary health services). Other behavioral factors present in related studies are largely absent in this context: coffee is not a health input (unlike many agricultural commodities); it accounts for a negligible share of total household consumption; and given Colombia's in-

[6] Our indirect estimates of infant mortality underreporting in Colombian vital statistics range from 30 percent to 45 percent; underreporting presumably varies with economic conditions. Other sources also document substantial underreporting in Colombia's mortality statistics (Flórez and Méndez 1997; Medina and Martínez 1999; PAHO 1999; Hill 2003; Urdinola 2004).

[7] This strategy exploits the fact that health is considerably more fragile in utero and during the first year of life than during the second or subsequent years (Dobbing 1976; Johnson, Moore, and Jeffries 1978; Barker 1992; Gazelian, Henry, and Olin 1992; Dietert et al. 2000; Selevan, Kimmel, and Mendola 2000).

stitutions, coffee prices are unrelated to the financing of local public programs (including health programs).

Changes in the return to coffee-related work are of course accompanied by competing income and substitution effects. Although we cannot separately identify each, we are able to estimate their combined influence. Because they work in opposite directions, this provides a direct test of the relative importance of time versus current income in household production of child health. Our results imply the primacy of time. Using intermediate outcomes, we also find additional evidence on the importance of time in health production (and in explaining procyclical mortality). First, coffee price reductions are associated with substantial declines both in the probability that adults work and in hours of work if employed (Dube and Vargas 2008). These declines are twice as large for women (the primary caregivers of children) as for men. Second, time-intensive child health investments are countercyclical. Third, childhood morbidity is procyclical, and when children are ill, parents are more likely to be at home than working outside the home if coffee prices are low. Fourth, births are countercyclical with a 1-year lag, suggesting the value of time to be an important determinant of other vital events as well (as prominently reported by Schultz [1985]).

We conclude by considering alternative explanations for procyclical mortality and conducting a variety of informal validity tests. We also cast our results in the context of a broader debate about the wealth-health relationship (McKeown 1976; Pritchett and Summers 1996) and the importance of parental time in the production of child quality (Mayer 1997; Blau 1999; Goldin 1999; Schady 2004; Kruger 2007; Price 2008). Overall, our findings are consistent with growing evidence that the relative price of health is a more powerful determinant of mortality than wealth (Preston 1975; Jamison, Sandbu, and Wang 2001; Cutler and Miller 2005; Cutler, Deaton, and Lleras-Muney 2006; Deaton 2006).

II. Coffee Cultivation in Colombia

A. *The Ecology of Coffee*

Arabica *caturra* coffee (the predominant variety grown in Colombia since the early 1970s) is a tropical plant requiring very specific environmental conditions for cultivation: temperatures between 15° and 24° Celsius, annual rainfall between 1,500 and 2,000 millimeters (depending on seasonal rainfall patterns and moisture retention of the soil), slopes of certain degrees at high altitudes (over 1,700 meters but below frost lines), and, depending on the circumstances, generous shade (Clifford and Wilson 1985). Tropical, high-altitude regions of Colombia are particularly well suited for coffee cultivation, especially the states of Antioquia, Caldas, Quindío, and Risaralda. Most coffee-producing nations have a single annual harvest, but Colombia's unusual ecology and rainfall allow for two harvests each year in some areas: a primary harvest between October and December and a secondary harvest in April–May (or the reverse in some areas). Figure 2 shows the geography of coffee cultivation in Colombia during the 1970s and 1980s at the *municipio* (hereafter county) level.

B. *Labor and Coffee Cultivation*

Coffee cultivation requires considerable nonharvest maintenance (including weeding, pruning, fertilizing, pest control, and renovation), and the use of labor for these purposes has a significant impact on the size of current-year coffee harvests (Clifford and Willson 1985; Ortiz 1999; Bacca 2002; CEDE 2002).[8] With the introduction of green revolution coffee varieties (*caturra* in particular) and the arrival of new fungal parasites ("rusts") in Colombia during the 1970s and 1980s, nonharvest labor as a share of total labor has grown considerably. During the harvest, coffee cherries must be picked immediately upon ripening to maximize their quality. Harvest windows for a given farm last approximately 2 weeks; during this period, picking cherries at their optimal stage of development can require visiting a single tree as many as eight times. After the harvest, coffee cherries must be processed (generally by the "wet" method in Colombia). This involves the use of pulping machines to soak and remove pulp from ripe cherries the day they are picked, fermenting the beans in tanks for 12–24 hours to loosen the remaining pulp and mucilage, washing to remove fermented residues, and drying either in the sun or using mechanical drying silos (CEDE 2002). This "parchment" coffee is then sold to distributors, who mill and bag Colombia's "green" coffee beans for export and sale to roasters.[9]

Labor on Colombian coffee farms generally falls into one of three categories: small farm owners who supply their own nonharvest labor, day laborers who live nearby and work year-round on the same farm, and seasonal migrant harvest workers. Since Colombia's agrarian reforms during the 1960s, most coffee is grown on small farms of 7 hectares or less (in 1997, average farm size was 1.7 hectares). This reduction in average farm size has made it possible for farm owners and their families to perform much of the nonharvest maintenance themselves. Larger

[8] County-year harvest data to demonstrate this are not available, but both the agricultural science literature and formal statements from the federation corroborate this point (Palacios 1980; Clifford and Willson 1985; Ortiz 1999; Bacca 2002; CEDE 2002; Silva 2004).

[9] Parchment coffee is dried coffee with a remaining hull or seed coat surrounding the bean. Once this hull is removed, the remaining green coffee is ready for export and roasting.

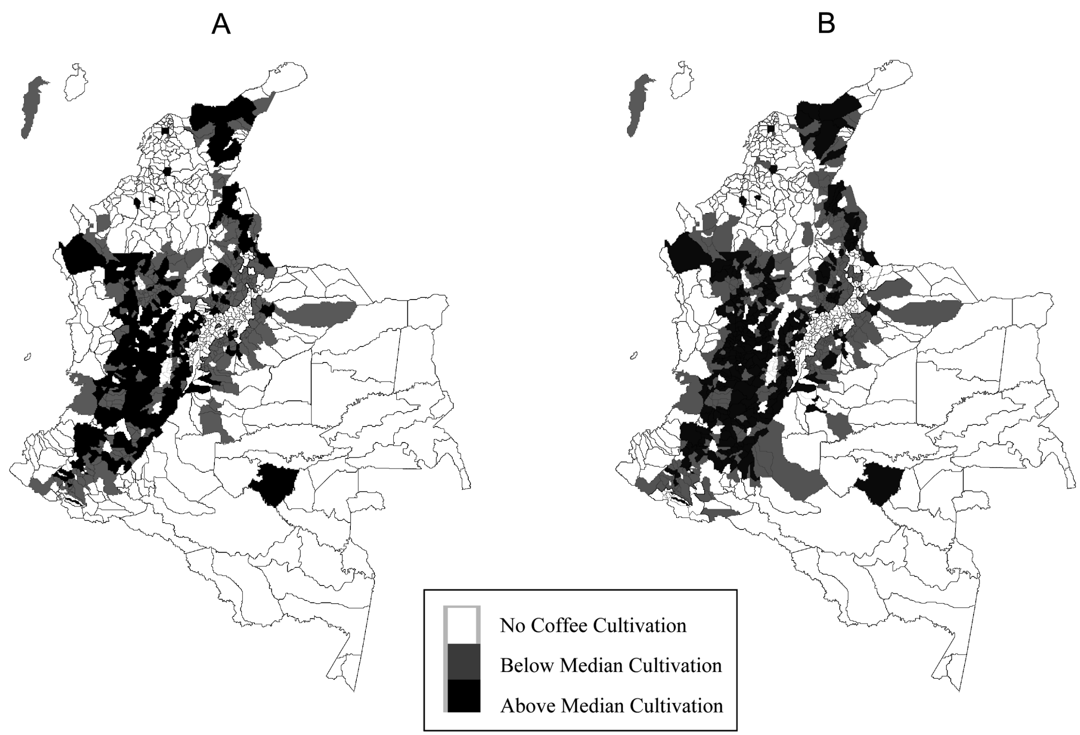

Fig. 2.—*A*, Cultivation in the 1970s; *B*, cultivation in the 1980s

farms also employ additional day labor in nonharvest seasons; day laborers are generally men, but many wives are hired to prepare meals for field workers and provide general support (Ortiz 1999). Finally, picking coffee cherries at their optimal ripeness requires additional short-term seasonal labor supplied by migrant harvest workers. These harvest workers are almost exclusively young unmarried men and constitute a modest (but important) part of the coffee workforce, moving from region to region for several months each year following the harvest (which varies according to altitude, rainfall, soil composition, etc.).

C. The National Federation of Coffee Growers of Colombia

Until industrialization occurred during the 1970s, coffee was Colombia's leading export. As a consequence, an unusual institutional arrangement to coordinate and manage coffee production developed in the form of the National Federation of Coffee Growers (NFCG, or Federación Nacional de Cafeteros de Colombia). The federation was established as a cooperative organization of coffee growers in 1927, but coffee's importance in the Colombian economy led the government to share in oversight and governance. It seeks both to advance the industrial interests of the Colombian coffee sector and to promote the welfare of coffee growers more broadly in rural regions historically neglected by government programs. It also ensures that Colombia adheres to its coffee export quotas under standing International Coffee Agreements (international treaties governing cartel-like behavior among coffee-producing nations) and operates an internal price support system for domestic growers. This system sets internal prices paid to growers as a function of world prices and partially shields them from world price volatility, paying more than growers would otherwise receive during bad years and less during good years (net of export costs and other markups).[10] These prices are uniform across the country: growers in all regions of Colombia are paid the same price for their coffee at any given point in time. Figures 3*A* and 3*B* show how internal prices paid to Colombian coffee growers vary with world coffee prices.

III. Data and Empirical Strategy

A. Data

We obtained average annual coffee prices for years 1970–2006 from the NFCG and the International Coffee Organization. Although household

[10] The NFCG managed these price distortions and compliance with export quotas through vast reserves of coffee beans. In 2001, the price support system was partially dismantled because of sustained low world coffee prices (CEDE 2002).

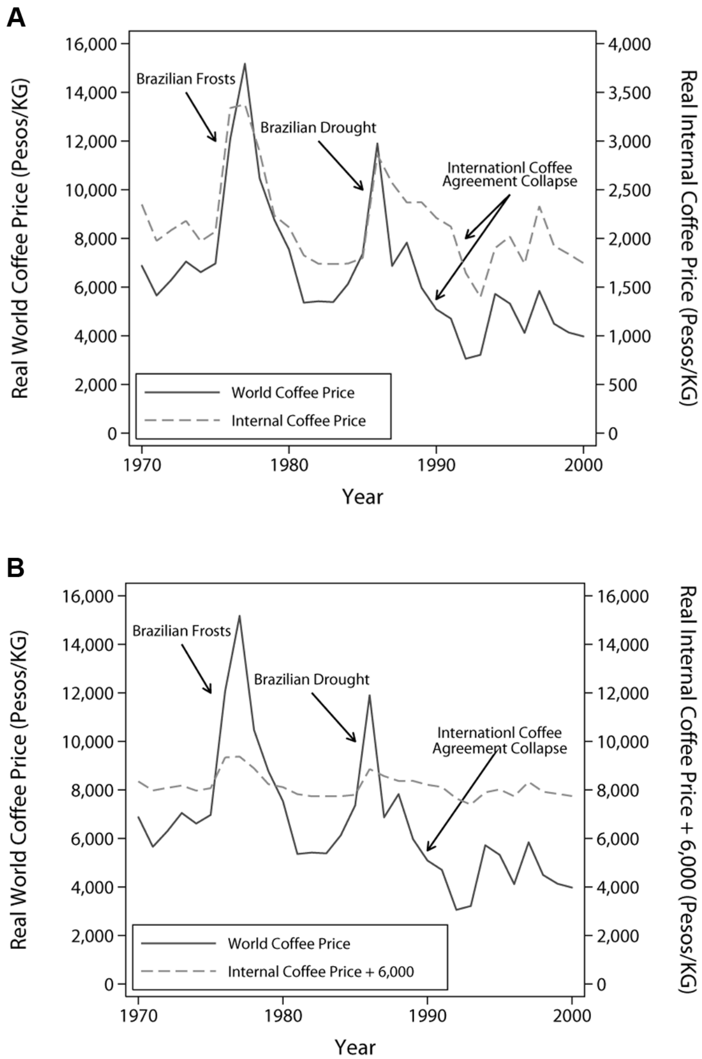

Fig. 3.—Real-world coffee prices and internal prices paid to Colombian coffee growers, 1970–2000.

choices do not influence world prices (and hence the determination of internal prices), we focus our analyses on price shocks known to originate outside of Colombia. As shown in figures 3*A* and 3*B*, these are frosts that destroyed much of Brazil's coffee harvest in 1975, a drought in Brazil in 1985, and the collapse of the International Coffee Agreement (ICA) in 1989–90 that led to the abandonment of export quotas by 1991. All three supply shocks led to dramatic changes in Colombia's internal coffee prices by as much as 40 percent of the long-run mean, and they allow us to study both sudden price increases and decreases.

Because prices paid to Colombian coffee growers do not vary by region, our identification strategy relies on the interaction between birth year coffee price and the intensity of birth county coffee production. We construct county-level intensity measures using the NFCG's decennial coffee censuses. For planning and monitoring purposes, the NFCG conducts decennial enumerations of all coffee farms in Colombia. We use these data from the early 1970s, early 1980s, and 1997 to measure hectares of coffee (or "intensity" of coffee cultivation) in each Colombian county as shown in figure 2.[11] (See App. B for a complete description of these data.) The timing of the NFCG's coffee censuses is convenient because they were generally conducted a few years before each major price shock that we analyze. New coffee cultivation cannot yield a harvest in less than 3–4 years (the biologically determined amount of time required for new coffee plants to produce their first fruit), so we can reasonably assume that our coffee intensity measures apply to shock years (Ortiz 1999; NFCG personal communication). Table 1 shows descriptive statistics for all of Colombia's counties and for counties with and without coffee cultivation.

To estimate how cohort size changes both with birth year coffee prices and in proportion to the intensity of birth county coffee cultivation, we construct birth county × birth year population counts using the 100 percent 1993 Colombian population census. Building population counts by county of birth rather than by county of residence minimizes the influence of migration (there was very little foreign emigration from Colombia during the years we study; Gaviria 2004; Garay and Rodríguez 2005; CELADE 2006). To address fertility responses, we also restrict our analysis of each price shock to cohorts born in shock years or earlier (i.e., only those conceived *prior* to shocks). We therefore interpret our population counts as reflecting survival (or cumulative mortality). This measure is free from many shortcomings of developing country vital registries.[12]

We also use Colombia's Demographic and Health Surveys (DHS) (and county-level child vaccination records described in App. B) to study more directly how time-intensive child health investments respond to coffee price fluctuations. These surveys contain detailed pregnancy

[11] For each price shock, we use the immediately preceding coffee census: the early 1970s census for the 1975 Brazilian frost, the early 1980s census for the 1985 Brazilian drought and the 1990 collapse of the ICA, and the 1997 census for our other more contemporary analyses.

[12] Appendix C shows that our calculations of infant mortality underreporting rates in Colombia range from 30 percent to 45 percent. Online App. F also shows demographic calculations evaluating the quality of the 1993 Colombian population census.

TABLE 1
DESCRIPTIVE STATISTICS

	ALL COUNTIES		COUNTIES WITH COFFEE		COUNTIES WITHOUT COFFEE	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
	A. Counties in the 1993 Population Census					
	$N = 1{,}060$		$N = 589$		$N = 471$	
Number of households	6,532	34,598	6,675	23,535	6,354	44,767
Number of individuals	30,942	174,651	30,200	106,237	31,869	233,683
Share female	.49	.02	.49	.02	.49	.02
Age	25.31	2.48	25.93	2.30	24.53	2.48
Share under age 5	.13	.02	.12	.02	.13	.02
Share married or in free union (over age 14)	.53	.12	.54	.07	.52	.16
Share born in current municipality	.66	.17	.65	.16	.67	.19
Share literate (over age 4)	.76	.18	.79	.11	.71	.23
Share in school (over age 4)	.26	.05	.25	.04	.27	.05
Years of education (over age 4)	3.62	.90	3.65	.84	3.59	.97
Share employed (over age 9)	.41	.10	.43	.06	.38	.12
Children ever born (females over age 14)	3.66	.52	3.65	.50	3.67	.55
Children alive (females over age 14)	4.11	.49	4.07	.48	4.15	.49
Age at last birth (females over age 14)	29.85	1.40	29.91	1.29	29.76	1.53
Share with brick or prefabricated walls	.47	.24	.47	.22	.48	.25
Share with adobe or pressed dirt walls	.20	.24	.21	.24	.18	.24
Share with dirt floors	.28	.22	.23	.18	.34	.24
Share with water access	.55	.26	.61	.23	.48	.28
Share with sewage access	.32	.25	.40	.24	.22	.23
Share with electricity	.67	.27	.73	.22	.60	.30
Number of household rooms	3.14	.43	3.22	.45	3.05	.39
Share owning home	.70	.17	.70	.12	.69	.22

TABLE 1
(*Continued*)

	All Counties		Counties with Coffee		Counties without Coffee	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Share renting or leasing home	.17	.11	.18	.10	.16	.11
Hectares of coffee (early 1980s)	979	1,871	1,726	2,209	0	.0
	B. Children in the Pooled Demographic and Health Survey Sample (1986, 1990, 1995, and 2000 Waves)					
	$N = 70{,}695$		$N = 22{,}313$		$N = 48{,}382$	
Mother's age	36.01	8.16	36.24	8.17	35.91	8.16
Mother's years of education	5.28	3.83	4.77	3.55	5.52	3.93
Number of household members	6.16	2.61	6.38	2.61	6.06	2.60
Mother's total number of births	4.40	2.73	4.76	3.00	4.24	2.58
Mother's age at first birth	19.84	3.92	19.83	3.90	19.84	3.93
Mother's age at first marriage	18.97	4.14	19.03	4.20	18.94	4.11
Preceding birth interval (months)	35.89	27.13	34.44	26.45	36.57	27.42
Share receiving prenatal tetanus toxoid	.68	.46	.65	.48	.70	.46
Share of mothers receiving prenatal care	.84	.37	.81	.39	.85	.36
Share of medically supervised births	.82	.39	.80	.40	.83	.38
Months breast-fed	9.66	8.69	9.11	8.69	9.91	8.68
Share receiving BCG vaccine	.92	.27	.93	.25	.91	.28
Share receiving DPT vaccine	.92	.28	.93	.26	.91	.28
Share receiving polio vaccine	.93	.25	.94	.24	.93	.26
Share receiving measles vaccine	.64	.48	.68	.46	.62	.49
Hectares of coffee in municipality (early 1980s)	1,899	3,136	2,974	3,493	0	.0
	C. Children in the Familias en Acción Survey Sample					
	$N = 13{,}732$		$N = 5{,}176$		$N = 8{,}556$	
Age	3.50	1.92	3.49	1.91	3.50	1.93

Share compliant with growth and development monitoring	.32	.47	.37	.48	.29	.45
Mother's age	31.15	7.01	31.05	6.82	31.21	7.13
Mothers: share with no education	.15	.35	.12	.32	.16	.37
Mothers: share with primary education	.21	.41	.20	.40	.21	.41
Mothers: share with secondary education or more	.06	.24	.06	.23	.06	.24
Mothers: share worked in preceding week	.35	.48	.34	.47	.35	.48
Mothers: monthly hours of work	36.69	77.19	38.30	78.55	35.66	76.30
Household head's age	40.57	12.33	39.97	12.00	40.95	12.53
Household head: share with no education	.23	.42	.19	.39	.26	.44
Household head: share with primary education	.11	.31	.09	.29	.11	.32
Household head: share with secondary education or more	.04	.20	.04	.19	.04	.21
Household head: share worked in preceding week	.91	.29	.91	.29	.91	.28
Household head: monthly hours of work	173.93	91.92	175.20	88.99	173.17	93.64
Number of people in household	6.60	2.53	6.53	2.51	6.64	2.54
Number of children in household (ages 0–6)	2.09	1.13	2.08	1.12	2.09	1.14
Share of children suffering acute diarrhea in last 15 days	.14	.35	.13	.34	.15	.36
Share of children suffering acute respiratory infection in last 15 days	.43	.5	.39	.49	.46	.50
Share of children suffering any illness in last 15 days	.55	.5	.52	.50	.57	.49
Share of children not participating in usual activities in last 15 days	.22	.41	.20	.40	.23	.42
Travel time in minutes to town center	56.29	101.12	55.04	64.39	57.08	118.54
Travel time in minutes to nearest health care facility	41.74	61.31	44.3	53.75	40.13	65.58

Source.—The data summarized in panel A are from the complete 1993 Colombian population census matched to the NFCG's early 1980s coffee census; the data summarized in panel B are from pooled child records from the 1986, 1990, 1995, and 2000 Colombian DHS also matched to the NFCG's early 1980s coffee census; the data summarized in panel C are from the Familias en Acción Survey (only 2002 first wave characteristics shown) matched to the NFCG's 1997 coffee census.

and child health histories for nationally representative samples of reproductive age women (defined as 15–49) in 1986, 1990, 1995, and 2000. We pool all four waves together to create a sample of child-level records that includes birth dates, maternal characteristics, preceding birth intervals, and detailed child health investment histories. Specific investments include maternal use of prenatal care, prenatal tetanus vaccinations, breast-feeding duration, and Expanded Program on Immunization (EPI) child vaccinations (*Bacillus Calmette-Guerin* [BCG]; diphtheria, pertussis [or whooping cough], and tetanus [DPT]; polio; and measles).[13] Women report this information for each of their children—regardless of their survival to the time of the survey—with the exception of child health histories, which are reported only for children born within 5 years of the survey. Panel B of table 1 shows descriptive statistics for Colombian children and their mothers in the pooled DHS sample.

Additionally, we use data from Colombia's Familias en Acción evaluation survey to investigate how local labor market conditions and parental time use change with coffee price fluctuations. This survey was first administered to 11,502 households in 122 Colombian counties in 2002; follow-up waves were conducted in 2003 and 2005 (Attanasio and Vera-Hernández 2004). Topical modules broadly cover household composition and demographic characteristics, labor force participation and other labor market conditions, and child health. Although these data were collected after the major coffee price shocks that we study, they contain detailed information not available from any other sources on employment, hours worked, time spent at home, travel time to health care facilities, and prevalence of childhood illness. Panel C of table 1 shows descriptive statistics for children and their parents in the Familias en Acción sample.

Finally, Appendix B describes in greater detail these data sources as well as others used for supplementary analyses in Section V.

B. *Empirical Strategy*

In a cohort study framework, we first estimate how cohort size varies in a way that is proportionate to both (i) internal birth year coffee price

[13] Developed in the 1930s, BCG reduces the likelihood and severity of tuberculosis in infants and young children. It is the most widely used vaccine in the world and the only available preventive tuberculosis vaccination. DPT is a combination of vaccines against all three infectious diseases. Polio and measles vaccines are preventive vaccines that protect against these respective diseases. The World Health Organization (WHO) recommends all of these vaccines before the age of 1 (although the measles vaccine is recommended beginning at 12 months in the United States). The WHO's original EPI initiative launched in 1974 focuses on these vaccines and has more recently expanded to encompass vaccination against yellow fever and hepatitis B. Prenatal tetanus toxoid immunizations protect newborns against neonatal tetanus, a leading killer of newborns in developing countries linked to nonsterile delivery.

and (ii) the economic importance of coffee in one's birth county (defined as farmland dedicated to coffee). Our specific measure of the impact of coffee price utilizes both sources of variation simultaneously. Constructed at the birth county × birth year level for counties (*municipios*) m and birth cohorts c, we implement this measure as

$$(\text{birth county coffee-growing intensity})_m \times$$

$$(\text{internal birth year coffee price})_c.$$

For simplicity, we write this term as $g_m \times p_c$.[14] As noted, this approach exploits the fact that health is considerably more fragile in utero and during the first critical year of life than during the second or subsequent years (Dobbing 1976; Barker 1992).[15] Because adjacent birth cohorts experience nearly identical conditions at every age except for the first year, we associate differences in survival between them with our coffee price measure during this critical developmental period.

We analyze each price shock shown in figure 3 separately: the 1975 Brazilian frost, the 1985 Brazilian drought, and the 1991 price collapse following the abandonment of ICA export quotas. We begin by restricting our analyses to samples of those in their first 2 years of life (ages 0–1 and ages 1–2) at the time that a coffee price shock occurred. Specifically, we estimate

$$\ln(s_{cm}) = \alpha + \lambda(g_m \times p_c) + \delta_m + \delta_c + \varepsilon_{cm}, \tag{1}$$

where s is the size of birth cohort c born in county m, δ_m and δ_c represent birth county and birth cohort fixed effects, and the parameter of interest is λ. Negative estimates of λ would imply countercyclical cohort size (which is consistent with procyclical mortality). We also estimate equation (1) using samples of those in their first 3 years of life when a price shock occurred, both with and without county-specific linear trends.[16] To test for differential reallocation of household resources by children's gender in response to price shocks, we estimate equation (1) separately for males and females as well.

After establishing the basic cyclical pattern of cohort size, we next

[14] Note that this product equals zero for counties with no coffee cultivation. Coffee prices are in real terms. Dube and Vargas (2008) independently developed a similar measure of coffee price shocks in Colombia.

[15] Death rates at ages 0–1 in the United States are at least 15 times greater than at ages 1–2 (NCHS 2002). Selective attrition is thought to play little role in explaining this age gradient and would only make it more difficult for us to detect meaningful mortality changes.

[16] Using samples of those aged 0–3 in price shock years, we estimate

$$\ln(s_{cm}) = \alpha + \lambda(g_m \times p_c) + \delta_m + \delta_c + \delta_m \times c + \varepsilon_{cm},$$

where $\delta_m \times c$ represents county-specific linear trends and all other variables are defined as in eq. (1).

consider what behavioral responses might explain these patterns. To study changes in the value of time, we use the Familias en Acción data (collected after the major coffee price shocks that this paper examines) to investigate the relationship between coffee price fluctuations and labor market outcomes underlying time-intensive child health investment decisions. For adult individuals i observed in years y and counties m, we estimate

$$o_{iym} = \alpha + \lambda(g_m \times p_y) + \delta_m + \delta_y + \delta_m \times y + \varepsilon_{iym}, \tag{2}$$

where o is a labor market outcome, δ_m, δ_y, and $\delta_m \times y$ represent county and year fixed effects and county-specific linear time trends (respectively), and the other variables are defined as before. Specific labor market outcomes that we examine separately for mothers and household heads include whether or not one worked the week prior to the survey (estimated using a probit model) and hours of work in the past month (both unconditionally and conditional on working in the past week).

We also use variants of equation (2) to investigate how the prevalence of childhood morbidity changes with price fluctuations. Then, to study how adult time use responds to price shocks when children are sick, we use a probit model to estimate

$$\begin{aligned}\Pr(t_{iym} = 1) = \Phi[&\alpha + \theta s_{iym} + \lambda(g_m \times p_y) + \mu(g_m \times s_{iym}) \\ &+ \sigma(p_y \times s_{iym}) + \rho(g_m \times p_y \times s_{iym}) + \delta_m + \delta_y \\ &+ \delta_m \times y + \varepsilon_{iym}],\end{aligned} \tag{3}$$

where t is a dichotomous indicator for adults' primary activity the day before the survey (either being at home or working outside the home), $\Phi[\cdot]$ is the standard normal cumulative density function, s is a dummy variable for whether or not a child in adult i's household was sick at the time of the survey, ρ is the parameter of interest, and all other variables are again defined as in previous estimating equations.

Finally, we use the pooled child-level DHS sample to examine specific health behaviors that are important in the first year of life. These analyses are again restricted to children aged 0–2 the year that a price shock occurred. Most health behavior measures are dichotomous, so we use probit models for children i, birth cohorts c, and counties m to estimate

$$\Pr(b_{icm} = 1) = \Phi\left[\alpha + \lambda(g_m \times p_c) + \sum_k \varphi_k w_{ik} + \delta_m + \delta_c + \varepsilon_{icm}\right], \tag{4}$$

where b is a dichotomous health behavior of interest (receipt of a prenatal tetanus toxoid vaccine, prenatal care, medical birth assistance, BCG vaccine, DPT vaccine, polio vaccine, or measles vaccine), w is a

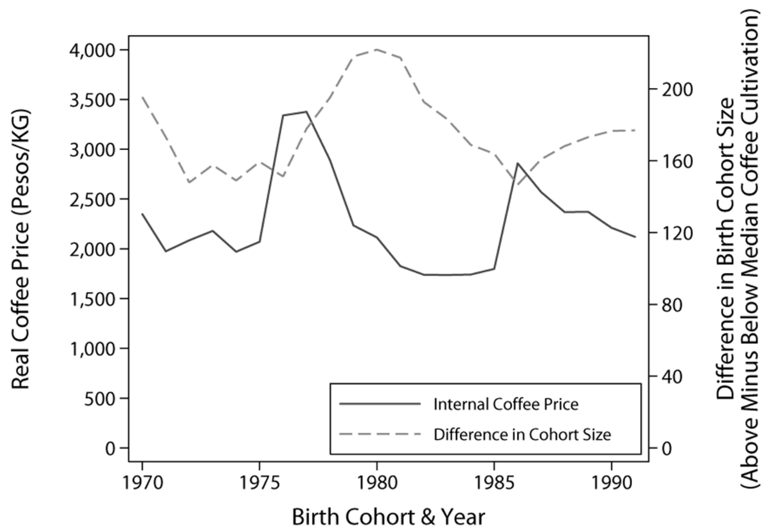

FIG. 4.—Coffee prices paid to Colombian growers and difference in birth cohort size between counties with above- and below-median coffee cultivation, 1970–91.

vector of maternal characteristics (mother's age, education, number of household members, number of preceding births, age at first birth, and age at first marriage), and all other variables are defined as before. (In complementary analyses, we also use Colombia's official county-year vaccination records to estimate variants of eq. [1].)

IV. Results: The Cyclicality of Child Survival, Time Use, and Child Health Investments

A. *Cohort Size*

Before formally estimating the association between cohort size and coffee prices, we first explore this relationship graphically. For the years 1970–93, figure 4 shows internal coffee prices and the difference in mean residual birth cohort size (net of county fixed effects) between counties with above- and below-median coffee intensity.[17] Although this graph includes all birth cohorts—and therefore does not distinguish between changes in fertility and changes in mortality—it clearly exhibits a pattern of countercyclical cohort size. (Despite the limitations of Colombia's mortality statistics, they exhibit a similar pattern; App. fig. A1

[17] Figure 4 is constructed using the 1980s measure of county-level coffee cultivation; constructing this graph using the 1970s coffee cultivation measure produces the same basic pattern.

TABLE 2
Coffee Price Shocks and ln(Cohort Size)

	Sample/Specification		
	Ages 0–2	Ages 0–3	Ages 0–3 with Trends
	A. 1975 Brazilian Frost		
Estimate	−.17***	−.03***	−.08***
	(.03)	(.01)	(.02)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Implied change	−2.16%	−.40%	−.99%
Observations	2,215	3,319	3,319
R^2	.99	.99	.99
	B. 1985 Brazilian Drought		
Estimate	−.16***	−.14***	−.23***
	(.04)	(.04)	(.09)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Implied change	−2.04%	−1.69%	−2.89%
Observations	2,208	3,310	3,310
R^2	.99	.99	.99
	C. 1990 ICA Collapse		
Estimate	−.10***	−.05***	.08
	(.03)	(.01)	(.06)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Implied change	−1.22%	−.58%	. . .
Observations	2,203	3,305	3,305
R^2	.99	.99	.99

Source.—County-year cohort size data are from the complete 1993 Colombian population census; coffee cultivation data are from the NFCG's early 1970s and early 1980s coffee censuses; and annual internal coffee price data are from the NFCG.

Note.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price in the first year of life are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends as shown above). Coffee area is in thousands of hectares and coffee prices are in thousands of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

reconstructs this graph using infant deaths rather than cohort size, showing procyclical infant mortality.)[18]

Table 2 shows estimates of λ (the coefficient for the interaction between birth year coffee price and birth county coffee intensity) obtained by estimating equation (1). Each panel reports results for different price shocks (1975, 1985, and 1991), and each column corresponds to a different sample or specification (those aged 0–2 at the time of a price shock, those aged 0–3, and those aged 0–3 controlling for county-specific

[18] Electronic Colombian mortality statistics are available only for 1979 and later.

linear trends). Because the dependent variable is in logarithmic form, coefficient estimates can roughly be interpreted as percentage changes in cohort size. To aid in interpretation, implied changes in cohort size are also shown for median coffee-growing intensity and a 500 peso price change.

Overall, table 2 presents evidence of countercyclical cohort size for all three price shocks.[19] For a county with median coffee cultivation, implied countercyclical changes in cohort size range from about −0.4 percent to −2.0 percent (with implied elasticities of −0.01 to −0.05). With cohort size interpreted as cumulative survival, this is consistent with procyclical mortality. Because the results in table 2 use population counts in 1993, it also suggests that deaths linked to coffee price fluctuations generally occur at young ages (the 1985 shock estimates are not smaller than the 1975 shock estimates, but the 1991 estimates are smaller than the 1985 estimates). If we assume that excess mortality related to price shocks occurs by age 5, our estimates imply that the largest price fluctuations since 1970 are associated with changes in child survival of approximately 15 percent.[20]

Table 3 shows estimates of λ obtained by estimating equation (1) separately for males and females. In contrast with other studies of consumption smoothing, intrahousehold resource allocation, and child mortality (Rose 1999), we find no evidence of statistically meaningful differences in cohort size (or survival) between boys and girls. This equivalence is consistent with other suggestions of little gender bias in intrahousehold resource allocation in Colombia (PROFAMILIA 2005; Hincapié 2006).

B. *Local Labor Markets, Infant/Child Morbidity, and Adult Time Use*

After establishing how cohort size covaries with coffee prices and the intensity of coffee cultivation, we then seek to understand the underlying behavior that explains these results. To focus more directly on the value of time, we first investigate how local labor market outcomes and adult time use respond to coffee price fluctuations. Micro data on labor market outcomes during the 1970s and 1980s are unavailable, so table 4 reports estimates of λ obtained by estimating equation (2) with the Familias en Acción survey data.

[19] The single exception is the 1991 price shock estimate in the sample of those aged 0–3 at the time of the shock conditional on county-specific linear time trends.

[20] For a mean birth year × birth county cohort size of 617, a 1 percent reduction implies 6.17 fewer people or 10 fewer people per 1,000. Mortality under age 5 in Colombia was about 60 per 1,000 in 1980 (Hill et al. 1999); $10/60 \approx 16$ percent. Presumably some mortality associated with price shocks occurs after age 5, in which case this is a slight overestimate of the true change in survival.

TABLE 3
Coffee Price Shocks and ln(Cohort Size) by Gender

	Sample/Specification: Male-Only Sample			Sample/Specification: Female-Only Sample		
	Ages 0–2	Ages 0–3	Ages 0–3 with Trends	Ages 0–2	Ages 0–3	Ages 0–3 with Trends
	A. 1975 Brazilian Frost					
Estimate	−.17***	−.04**	−.08***	−.17***	−.03**	−.08***
	(.04)	(.02)	(.02)	(.03)	(.01)	(.02)
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
County-specific linear trends	No	No	Yes	No	No	Yes
Implied change	−2.09%	−.48%	−1.01%	−2.15%	−.38%	−.97%
Observations	2,207	3,305	3,305	2,205	3,307	3,307
R^2	.99	.99	.99	.99	.99	.99
	B. 1985 Brazilian Drought					
Estimate	−.16***	−.15***	−.20***	−.17***	−.13***	−.25**
	(.05)	(.05)	(.11)	(.06)	(.05)	(.11)
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
County-specific linear trends	No	No	Yes	No	No	Yes
Implied change	−2.04%	−1.81%	−2.49%	−2.13%	−1.63%	−3.13%
Observations	2,199	3,299	3,299	2,205	3,305	3,305
R^2	.99	.99	1.00	.99	.99	.99
	C. 1990 ICA Collapse					
Estimate	−.09**	−.05**	.03	−.10***	−.04***	.11
	(.04)	(.01)	(.08)	(.04)	(.01)	(.08)
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
County-specific linear trends	No	No	Yes	No	No	Yes
Implied change	−1.13%	−.67%	. . .	−1.23%	−.46%	. . .
Observations	2,199	3,300	3,300	2,198	3,298	3,298
R^2	.99	.99	.99	.99	.99	.99

Source.—County-year cohort size data are from the complete 1993 Colombian population census; coffee cultivation data are from the NFCG's early 1970s and early 1980s coffee censuses; and annual internal coffee price data are from the NFCG.

Note.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price in the first year of life are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends as shown above). Coffee area is in thousands of hectares and coffee prices are in thousands of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

TABLE 4
COFFEE PRICE SHOCKS AND LOCAL LABOR MARKETS

	Estimate	Implied Change	Observations	R^2/ Pseudo R^2
Mother: worked last week?	.02* (.01)	.05	11,110	.04
Household head: worked last week?	.02*** (.01)	.05	18,093	.05
Mother: hours of monthly work	4.81* (2.77)	9.81	8,757	.10
Household head: hours of monthly work	5.85*** (1.96)	11.93	16,737	.05
Mother: hours of monthly work (conditional on worked last week)	6.84 (4.88)	. . .	3,369	.08
Household head: hours of monthly work (conditional on worked last week)	2.06 (1.72)	. . .	15,236	.04

SOURCE.—Individual-level market participation data are from the Familias en Acción panel survey (2002, 2003, and 2005 waves); coffee cultivation data are from the NFCG's 1997 coffee censuses; and annual internal coffee price data are from the NFCG.

NOTE.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price are obtained by estimating eq. (2) (controlling for county and year fixed effects and country-specific linear trends as shown above). For dichotomous dependent variables (the first two rows), a probit model was used to estimate eq. (2), and marginal probabilities are reported. Coffee area is in hundreds of hectares and coffee prices are in hundreds of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.

* $p < .1$.
** $p < .05$.
*** $p < .01$.

Focusing on labor force participation, the first and second rows of table 4 show marginal probabilities (calculated using probit estimates and independent variable means) implying that a 500 peso price decline in a county with median coffee cultivation is associated with a 5-percentage-point decrease in the probability that either a mother or a household head worked during the preceding week. Because mothers generally work less than household heads, this reduction is a 14 percent decline for mothers versus a 5 percent decline for household heads. The third and fourth rows then imply that the same price shock is associated with working 10 and 12 fewer hours per month, respectively.[21] These reductions are again larger in relative terms for mothers (27 percent) than for household heads (7 percent). Conditional on working the week prior to the survey, the fifth and sixth rows show that reductions in hours worked are statistically indistinguishable from the unconditional estimates but are also not statistically different from zero at conventional levels.

[21] About 10 percent of household heads and 18 percent of mothers are missing data for hours worked. Missing data are not correlated with intensity of coffee cultivation; for more discussion of missing data in the Familias en Acción survey, see Attanasio and Vera-Hernández (2004). The estimates presented in table 4 are generally insensitive to restricting the analyses to women with complete data for all variables examined.

TABLE 5
Coffee Price Fluctuations, Infant/Child Morbidity, and Adult Time Use

	Estimate	Implied Change	Observations	R^2/ Pseudo R^2
	A. Child Morbidity within the Preceding 15 Days			
Acute diarrhea	.009**	.12	29,786	.03
	(.004)			
Acute respiratory infection	.022***	.28	29,771	.04
	(.006)			
Any childhood illness	.022***	.28	29,775	.03
	(.006)			
Child absent from usual activities because of illness	.025***	.32	29,707	.02
	(.005)			
	B. Adult Time Use the Preceding Day Conditional on Child Illness			
Working outside of the home for money	.007	. . .	20,554	.04
	(.014)			
Working in self-employed occupation	.011*	.13	20,557	.05
	(.006)			
At home doing household activities	−.027*	−.34	18,779	.06
	(.016)			

Source.—Individual-level child morbidity symptom data and adult time use data are from the Familias en Acción panel survey (2002, 2003, and 2005 waves); coffee cultivation data are from the NFCG's 1997 coffee censuses; and annual internal coffee price data are from the NFCG.

Note.—Panel A shows marginal probabilities (and corresponding standard errors in parentheses, clustered by county) for the interaction between coffee-growing intensity and coffee price. They were calculated using estimates from eq. (2) fit using probit models (controlling for county and year fixed effects and county-specific linear trends). Panel B shows marginal probabilities (and corresponding standard errors in parentheses, clustered by county) for the three-way interaction among coffee-growing intensity, coffee price, and a child in the household having missed usual activities because of illness in the preceding 15 days. They were calculated using estimates from eq. (3) fit using probit models (controlling for the childhood illness measure, all lower-order interactions, day of the week, county and year fixed effects, and county-specific linear trends). Coffee area is in hundreds of hectares and coffee prices are in hundreds of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.

* $p < .1$.
** $p < .05$.
*** $p < .01$.

Next, we use the Familias en Acción data to investigate how coffee price fluctuations are related to the incidence of childhood illness—and to adults' choices to stay at home or work outside the home when children are sick. With dichotomous indicators for various childhood illnesses within the past 15 days (acute diarrhea, acute respiratory infection, any illness, or missing usual activities because of illness) used as dependent variables, panel A of table 5 reports marginal probabilities calculated from probit estimates for the interaction between coffee cultivation and coffee price. Childhood morbidity is procyclical for all illness measures; implied changes range from 10 percent to 30 percent for a 500 peso price change at median coffee cultivation.

To investigate how adult time use varies with coffee prices when children are ill, we then estimate equation (3) using several dichotomous measures of adult time use the day before the survey. These include working outside the home for money, self-employed working at home, and not working but at home doing household chores; we interpret the last as including child care. Our measure of childhood illness is having missed usual activities because of illness in the past 15 days. Panel B of table 5 shows marginal probabilities for the three-way interaction of coffee cultivation, coffee price, and childhood illness. When a child is sick and coffee prices are high, adults in areas with greater coffee cultivation are more likely to be working (in self-employed occupations in particular) and less likely to be doing household chores (which presumably include child care).

Taken together, these patterns of labor market activity, childhood illness, and adult time use when children are ill suggest that parental time may play an important role in explaining procyclical infant and child mortality.

C. *The Value of Time and Infant/Child Health Investments*

We next study the cyclicality of time-intensive child health investments. Many health investments that we observe are linked to the use of primary and preventive health services. Importantly, these services are generally inexpensive or free in Colombia but require considerable travel and long waiting times. Other important time-intensive child health investments that we do not observe (e.g., trips to distant clean wells and good household hygiene) can reasonably be assumed to vary in the same cyclical manner.

Using the pooled DHS sample to estimate equation (4), table 6 shows marginal probabilities corresponding to estimates of λ for preventive health service use in the first year of life.[22] All estimates that are distinguishable from zero are negative, implying countercyclical health investments. As Section V.A explains, local coffee revenue and local public health budgets are not linked, so these relationships are presumably demand driven.

We then use Colombia's official county-year EPI vaccination records from years 1998–2007 to estimate equation (1) (App. B describes these data). These vaccines include polio, DPT, BCG (against tuberculosis), hepatitis B, *Haemophilus influenzae* type B (against Hib disease manifestations such as pneumonia and meningitis), and measles, mumps, and rubella (MMR). Table 7 shows estimates for the interaction parameter

[22] Sample sizes for the 1985 price shock analyses are smaller because early DHS waves report health investments only for children born within 5 years of the survey date. For this reason, the 1975 price shock cannot be analyzed. In addition, later waves that reported health investment information for all children—not just those born within 5 years of the survey date—did so for some investments (primarily prenatal and neonatal services) but not for others.

TABLE 6

Coffee Price Shocks and Infant Health Investments

	Estimate	Implied Change	Observations	R^2/ Pseudo R^2
	A. 1985 Brazilian Drought			
Prenatal tetanus toxoid	−1.08*** (.37)	−.135	1,082	.19
Prenatal care	−.36 (.31)	. . .	1,055	.17
Birth assistance	−.17 (.32)	. . .	1,034	.25
Months breast-fed	−.53 (4.93)	. . .	1,218	.20
BCG vaccine	.29 (.37)	. . .	490	.15
DPT vaccine	.00 (.00)	. . .	531	.13
Polio vaccine	−.01*** (.01)	−.002	540	.12
Measles vaccine	.33 (.48)	. . .	574	.12
	B. 1990 ICA Collapse			
Prenatal tetanus toxoid	.25 (.51)	. . .	1,790	.17
Prenatal care	−.67* (.42)	−.084	1,815	.13
Birth assistance	.87 (.42)	. . .	1,668	.18
Months breast-fed	12.60 (10.00)	. . .	1,939	.17
BCG vaccine	−.04 (.28)	. . .	1,397	.15
DPT vaccine	−.04 (.25)	. . .	1,631	.25
Polio vaccine	.02 (.16)	. . .	1,743	.25
Measles vaccine	−.06 (.17)	. . .	1,096	.25

Source.—Individual-level infant health input data are from the pooled 1986, 1990, 1995, and 2000 Colombian DHS sample; coffee cultivation data are from the NFCG's early 1980s coffee census; and annual internal coffee price data are from the NFCG.

Note.—Marginal probabilities (and corresponding standard errors in parentheses, clustered by county) are shown for the interaction between coffee-growing intensity and coffee price and were calculated using estimates obtained from eq. (4) (controlling for county and year fixed effects and county-specific linear trends as well as mother's age, education, number of household members, number of preceding births, age at first birth, and age at first marriage) with the exception of months breast-fed, for which an ordinary least squares estimate is reported. Breast-feeding results are generally invariant to methods of addressing censoring in the distribution of months breast-fed. Coffee area is in thousands of hectares and coffee prices are in thousands of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

TABLE 7
COFFEE PRICE FLUCTUATIONS AND WHO EPI BUNDLE VACCINATIONS

Vaccination Type	Estimate	Implied Change	Observations	R^2
ln(polio vaccinations)	−.44*** (.11)	−5.54%	7,600	.94
ln(DPT vaccinations)	−.38*** (.12)	−4.78%	7,603	.92
ln(BCG vaccinations)	−.30*** (.12)	−3.76%	7,573	.94
ln(hepatitis B vaccinations)	−.60*** (.12)	−7.51%	7,604	.93
ln(*Haemophilus Influenzae* type B vaccinations)	−.58*** (.15)	−7.25%	7,018	.90
ln(MMR vaccinations)	−.53*** (.12)	−6.68%	7,611	.93

SOURCE.—County-year WHO EPI vaccination data for years 1998–2007 are from Fundación Santa Fe de Bogotá; coffee cultivation data are from the NFCG's 1997 coffee census; and annual internal coffee price data are from the NFCG.
NOTE.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends). Coffee area is in thousands of hectares and coffee prices are in thousands of pesos per kilogram. Implied changes are calculated for 250 hectares of coffee and a 500 peso per kilogram price change.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

λ: all estimates are negative and statistically distinguishable from zero, suggesting countercyclical fluctuations in vaccination use.

Overall, tables 6 and 7 establish a general countercyclical pattern of health behaviors requiring substantial parental time. Prominent estimates linking child survival with time-intensive health investments that we do not observe suggest that plausible changes in water fetching (and water quality), household hygiene, and primary health care use alone could explain the mortality changes implied by our cohort size results.[23] Online Appendix E presents additional evidence on the value of time in determining the use of other health inputs and vital events as well.

V. Alternative Explanations for Procyclical Infant/Child Mortality

This section considers alternative explanations for our findings, including those proposed by wealthy country studies documenting procyclical mortality (Ruhm 2000, 2006). Specifically, we examine cyclical patterns of local public spending, NFCG "social investments," alcohol and tobacco use, traffic fatalities, and other violent deaths. We then summarize

[23] These health behaviors are leading determinants of child survival (Murray and López 1997; WHO 2002, 2005). Key estimates are provided by Esrey et al. (1991), Cutler and Miller (2005), Fewtrell et al. (2005), Luby et al. (2005), Miller (2008), Bjorkman and Svensson (2009), and Jayachandran and Lleras-Muney (forthcoming).

several informal tests of the validity of our empirical approach (presented fully in App. D).

A. *Alternative Mechanisms*

1. Local Public Spending

Coffee cultivation and production in Colombia are not taxed (Cárdenas 1994; Cárdenas and Yanovich 1997; Cárdenas and Partow 1999; Cuellar 2004), and central government transfers to local governments follow rigid budget cycles that do not adjust flexibly to local economic circumstances. In exchange for the lack of formal taxation, the NFCG has a long-standing agreement with the Colombian government to finance development projects in coffee-growing regions on its own (we analyze this NFCG financing in the next subsection). The result is that coffee price fluctuations do not have an important immediate impact on local public revenue or local public programs.[24] To provide econometric support for this assertion, we use a county-year panel of local public finance data for years 1984–93 collected by the Contraloría General de la Nación (the accounting branch of the Colombian government; see App. B for a description of these data) to regress county-year tax revenue and public spending on interactions between coffee prices and coffee cultivation (following eq. [1]). Appendix table A1 shows estimates for the interaction between coffee price and coffee cultivation. The absence of statistically meaningful estimates is consistent with our view that coffee price shocks do not act primarily through the financing of public programs.

2. Social Contribution Spending by the NFCG

Because the NFCG devotes some of its revenue to development projects in coffee-growing regions (termed NFCG "social contribution" spending), we also investigate whether or not cyclical changes in social contributions could explain our findings. Prima facie evidence against a meaningful role of NFCG social spending is the fact that it generally focuses on infrastructure projects, responding very slowly to revenue

[24] National government transfers account for a large share of local government spending on public services. Otherwise, 75–80 percent of counties' own tax base is raised through real estate and industry taxes, neither of which can respond rapidly to coffee price fluctuations (Zapata, Acosta, and González 2001; Cadena 2002; Núñez 2005; Bonet 2006). Any immediate indirect effect of coffee price fluctuations on local public finance (through changes in consumption, e.g.) would therefore be small.

fluctuations.[25] We reestimate equation (1) using a department-level panel of NFCG social contribution spending for the years 1979–2004 (with department rather than county fixed effects and linear trends; see App. B for a description of these data). We find no statistically meaningful relationship between coffee prices and department-level NFCG social spending.[26]

3. Traffic Fatalities and Violent Deaths

Wealthy country studies that report procyclical mortality suggest that traffic fatalities may play an important role (Ruhm 2000). Given high levels of violence in Colombia, cyclical changes in violent deaths may also be quantitatively meaningful.[27] To consider these possibilities, we obtained county-year data on traffic fatalities and violent deaths for the years 1979–2001 from the Colombian national statistical agency (App. B describes these data). Panel A of Appendix table A2 shows coefficient estimates for coffee price × coffee cultivation interactions when using these measures as dependent variables in equation (1); neither estimate is statistically distinguishable from zero.

4. Alcohol and Tobacco Consumption

Procyclical consumption of harmful normal goods (alcohol and tobacco) is also a potential contributor to procyclical mortality (although the consequences for infants and children may be less than for adults; Ruhm 2000). Because disaggregated Colombian alcohol and tobacco sales data are unavailable, we obtained annual department-level tax revenue data from beer, hard liquor, and tobacco sales for the years 1990–2001 (App. B describes these data). Although we lack explicit information about tax rates and pretax prices over time, Colombian alcohol and tobacco tax rates have been stable in recent decades (with the exception of legislated national changes in 1995 and 2006). Considering these tax revenue measures to be crude proxies for consumption, we use them as dependent variables to reestimate equation (1). Panel B of

[25] The NFCG board of directors distributes its social contribution across coffee-growing regions, focusing on agricultural research, business development, publicity, and infrastructure projects (roads, electricity, school construction, etc.; Silva 2004).

[26] When we use coffee area in thousands of hectares and coffee prices in thousands of pesos per kilogram, the coefficient estimate on the interaction between department-level coffee cultivation and annual coffee price is -0.0003 with a standard error of 0.002 ($N = 404$, $R^2 = 0.96$).

[27] Using different data, Dube and Vargas (2008) suggest that during later years with substantially more conflict, low coffee prices are associated with more conflict-related events, invoking the opportunity cost of time to explain this relationship.

Appendix table A2 suggests that none change meaningfully with coffee price fluctuations.

B. *Informal Validity Tests*

We also consider threats to the internal validity of our analyses; Appendix D presents informal validity tests, which we summarize here. Given our empirical framework, any confounding influence must have varied both over time in the same erratic manner as world coffee prices and across counties in proportion to coffee cultivation intensity. The most natural concerns are (1) that we mistake changes in the composition of births or women giving birth for mortality responses and (2) that interacting plausibly exogenous price shocks with endogenous measures of coffee cultivation causes us to mistake selection effects for true behavioral responses.[28] Appendix D presents evidence suggesting that neither concern seems important in practice.

VI. Conclusion

This paper uses large world coffee price fluctuations to understand the cyclical nature of infant and child mortality in Colombia. Despite the presence of credit constraints and other market imperfections leading to incomplete consumption smoothing, we document a striking pattern of procyclical mortality. We also show that a key behavioral underpinning of procyclical mortality appears to be changes in the value of time associated with world coffee price shocks. Time is a critical health input—many of the leading determinants of child survival in developing countries are inexpensive but require large amounts of time—so all else equal, the relative price of health falls with the return to working.

Our results are also consistent with growing evidence on the primacy of time in the production of overall child quality. Studies of school enrollment in American history and in contemporary developing countries report patterns of procyclical child labor and countercyclical school enrollment and similarly link these patterns to the opportunity cost of time (Goldin 1999; Schady 2004; Kruger 2007). Other studies of child development have cast doubt over the importance of material resources per se—and transitory income in particular—for the cognitive, social, and emotional development of children (Mayer 1997; Blau 1999; Price 2008).

Finally, our findings directly relate to the broader debate about the

[28] Changes in coffee cultivation cannot influence harvest size in less than 3–4 years (the biologically determined amount of time between planting and first harvest for new coffee groves; Ortiz 1999).

wealth-health relationship. Although wealth has prominently been proposed as an important determinant of mortality (McKeown 1976; Pritchett and Summers 1996), there is a growing suggestion that reductions in the relative price of health (due to technological progress in public health, e.g.) are more important in explaining observed declines in mortality across time and space (Preston 1975; Jamison et al. 2001; Cutler and Miller 2005; Cutler et al. 2006; Deaton 2006). Our results are consistent with this view.

Appendix A

TABLE A1
Coffee Price Fluctuations and County-Level Public Finance

	Estimate	Observations	R^2
Total local government income	.002	8,020	.95
	(.024)		
Transfer income	−.005	8,020	.90
	(.006)		
Capital income	.000	8,020	.71
	(.001)		
Total direct taxes	−.001	8,020	.94
	(.008)		
Total indirect taxes	.008	8,020	.96
	(.012)		
Industry and commerce taxes	.005	8,020	.96
	(.007)		
Total spending	−.005	8,020	.92
	(.039)		
Investment spending	−.013	8,020	.90
	(.019)		
Operational spending	.003	8,020	.94
	(.017)		
Water spending	−.001	8,020	.39
	(.002)		
Infrastructure spending	−.008	8,020	.68
	(.006)		
Housing spending	−.001	8,020	.53
	(.005)		
Education spending	−.001	8,020	.77
	(.003)		
Health spending	.001	8,020	.75
	(.002)		

Source.—County-year public finance data for years 1984–93 are from Contraloria General de la Nación; coffee cultivation data are from the NFCG's early 1980s coffee census; and annual internal coffee price data are from the NFCG.

Note.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends). Coffee area is in hectares and coffee prices are in pesos per kilogram.

TABLE A2
Coffee Price Fluctuations, Traffic Fatalities, and Violent Deaths

	Estimate	Observations	R^2
	A. County-Level Traffic Fatalities and Violent Deaths		
ln(motor and other land transportation deaths)	.015 (.024)	12,104	.81
ln(violent deaths)	.012 (.007)	11,722	.85
	B. Department-Level Alcohol and Tobacco Tax Revenue		
ln(beer sales)	−.006 (.007)	396	.99
ln(liquor sales)	−.014 (.023)	384	.97
ln(tobacco sales)	.009 (.011)	394	.94

Source.—County-year numbers of traffic fatalities and violent deaths for years 1979–2001 are from the Departamento Administrativo Nacional de Estadística; department-year beer, liquor, and tobacco sales tax data are from Contraloria General de la Nación; coffee cultivation data are from the NFCG's early 1980s coffee censuses; and annual internal coffee price data are from the NFCG.

Note.—Estimates and standard errors (in parentheses, clustered by county for panel A and department for panel B) shown for the interaction between coffee-growing intensity and coffee price are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends in panel A and controlling for department and year fixed effects and department-specific time trends in panel B). Coffee area is in thousands of hectares and coffee prices are in thousands of pesos per kilogram.

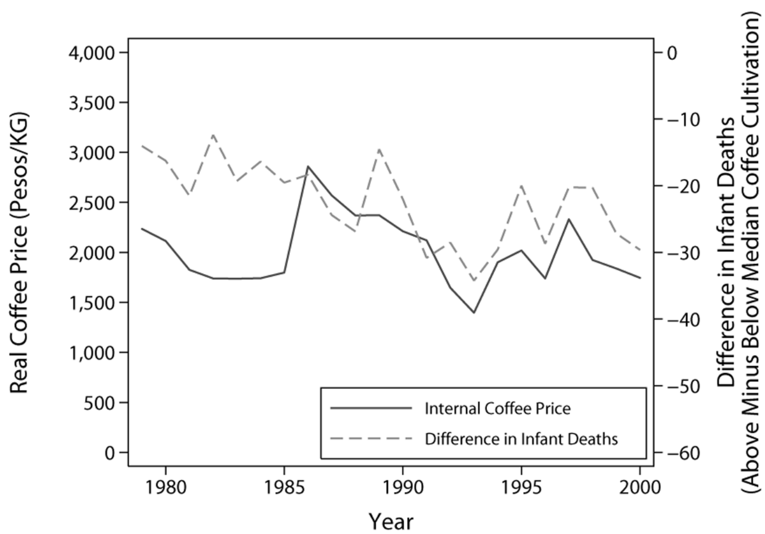

Fig. A1.—Coffee prices paid to Colombian growers and difference in infant mortality between counties with above- and below-median coffee cultivation, 1979–2000.

Appendix B

Data

NFCG and the International Coffee Organization: Coffee Prices

We initially obtained average annual internal coffee prices paid to Colombian coffee growers for years 1970–2006 from two sources: the London-based International Coffee Organization (ICO) and the NFCG. Internal prices paid to Colombian coffee growers at a given point in time do not vary within the country. The ICO's price data are obtained directly from the NFCG, so we generally use the latter. (The single exception is our analyses using Familias en Acción survey data. Because the last wave of the survey was conducted in 2005/6—but the NFCG provided price data only through 2004—we use real ICO price data in U.S. dollars.) We then converted the NFCG time-series price data (obtained in Colombian pesos per kilogram of "green" coffee) to real 1998 terms using the official consumer price index constructed and published by the Colombian Central Bank (Banco de la República). This price index is available online at http://www.banrep.gov.co/estad/dsbb/srea_012.xls.

NFCG: Coffee Cultivation

Approximately once per decade, the NFCG conducts a complete enumeration of all coffee growers in Colombia for planning and monitoring purposes. The 1970 coffee census combined information collected directly from coffee growers with land use data gathered through aerial photography. Drawing on the experiences of the 1970 census, the 1980–81 coffee census was conducted primarily using aerial photography with field verification for purposes of quality control. The 1997 coffee census was based on a complete enumeration (on the ground) of all coffee growers between 1993 and 1997. In all of our analyses, we use the immediately preceding coffee census conducted prior to a given price shock. (Because new coffee plants require 4 years to produce their first mature harvest, areas dedicated to coffee cultivation cannot respond quickly to changes in world coffee markets.)

The 1970 and 1980 coffee censuses are available only in hard-copy format from the NFCG. With special permission from the NFCG, we digitized county-level indicators of coffee cultivation from each census using these printed volumes. The principal measure relevant to our analyses is hectares of land dedicated to coffee cultivation. The 1997 coffee census is available in electronic format.

100 Percent 1993 Colombian Population Census: Birth Cohort Size

We constructed birth cohort size counts at the county–birth year level using the complete (100 percent) 1993 Colombian population census obtained from the Colombian National Statistical Agency (Departamento Administrativo Nacional de Estadística [DANE]). These birth cohort counts were generated using detailed geographic identifiers that allow all counties to be recognized according to each individual's county of birth, not county of residence in 1993. There were 32,451,229 noninstitutionalized individuals in 1,060 counties recorded in the 1993 population census. These counties account for all of Colombia in a mutually exclusive and collectively exhaustive manner. Birth cohort counts were then matched to (i) prevailing real internal coffee prices in each cohort's year of birth and (ii) the most recent county-level coffee cultivation measures prior to that year in each cohort's county of birth.

DHS: Health Investments and Maternal Socioeconomic Status

Our primary measures of health investments and mothers' socioeconomic status are obtained from four waves of Colombia's DHS. These are nationally representative surveys of fertile age women (defined as 15–49) in the year a survey is conducted. We pool the four DHS waves together using variables reported in a comparable manner over time. (The first wave in 1986 was conducted by the Corporación Centro Regional de Población; the 1990, 1995, and 2000 waves were conducted by the Asociación Pro-Bienestar de la Familia Colombiana [PROFAMILIA].) Public-use DHS data are available for download by registering at http://www.measuredhs.com/. Using the child recode files matched to maternal characteristics (a pooled sample of 70,695 children), we then match each child to (i) the prevailing real internal coffee price in his or her year of birth and (ii) the most recent county-level coffee cultivation measures prior to the child's birth year according to county of residence at the time of the survey (county of birth is not recorded in the DHS data). Individual counties are not identified in the publicly available Colombian DHS data, but PROFAMILIA and Macro International (the U.S.-based DHS partner) provided keys that match sampling clusters to individual counties.

Available measures of health investments reported consistently across the four waves include maternal use of prenatal care, prenatal tetanus vaccinations, birth assistance, breast-feeding duration, and a variety of child vaccinations (BCG, polio, DPT, and measles). This mother-reported information can be divided into two categories: birth histories and child health histories. The birth histories are reported for every live birth (regardless of child survival to the survey date) and include prenatal care, prenatal tetanus vaccinations, birth assistance, and breast-feeding duration. The child health histories are reported for all children born within 60 months of the survey date (regardless of child survival to the survey date) up to a maximum of six children per woman and include BCG, polio, DPT, and measles vaccinations. Maternal socioeconomic characteristics for each child that are available in all four waves include age, educational attainment in years, number of preceding births, preceding birth interval, age at first birth, age at first marriage, and number of household members.

Familias en Acción Evaluation Survey: Local Labor Markets, Child Morbidity, and Time Use

Our data on rural labor markets, childhood morbidity, adult time use, and travel time to health care facilities are drawn from three waves of a household panel survey conducted to evaluate the Familias en Acción program in Colombia.

Familias en Acción is a nonrandomized conditional cash transfer program similar to Mexico's *Oportunidades* program (formerly known as *Progressa*). The survey was first conducted in 2002 with follow-up surveys repeated in 2003 and 2005/6. In 2002, the baseline survey was administered to 11,502 households in 122 Colombian counties. Attrition rates for the two follow-up surveys relative to the first wave were 6.3 percent and 17.1 percent. Topical survey modules broadly covered household demographic characteristics and composition, consumption, income, school attendance and educational attainment, and labor force participation. In addition, detailed health questions—including adult-reported symptoms of child morbidity and child preventive health care service use—were asked for all children 6 years of age and younger. Although the Familias en Acción survey data do not extend back to the three major world coffee price shocks studied by this paper, the survey collected complementary data relevant to our analyses but not available in any other data source on employment, wages, hours worked, adult time use, and travel time to health care facilities.

WHO EPI Colombian Vaccination Records

To investigate how infant/child vaccinations move with coffee prices, we obtained county-year vaccination records covering the years 1998–2007 for the following vaccines: polio, DPT, BCG, hepatitis B, *Haemophilus influenzae* type B (against the variety of Hib disease manifestations, including meningitis and pneumonia), and MMR. The Colombian Ministry of Health is formally responsible for reporting aggregate national vaccination coverage data to the WHO. However, it does not store and maintain disaggregated vaccination data for preceding years. To facilitate the study of vaccination coverage, a private organization (Fundación Santa Fe de Bogotá) has therefore conducted a project in conjunction with the Ministry of Health to collect disaggregated vaccination data from each Colombian county. To date, this project has collected retrospective county-level vaccination data for the years 1998–2007. The foundation has generously provided these data to us, and we have merged these vaccination records with the 1997 coffee census and annual internal coffee prices.

Contraloría General de la Nación: Colombian Local Public Finance Records

We obtained county-year-level data on local public revenue and spending collected by Contraloría General de la Nación (the senior accounting branch of the Colombian government). Contraloría obtains these data from each county's official balance sheets. The data are available for the years 1984–93 and include current income, transfers, capital income, tax income, direct taxes, indirect taxes, industry and commerce taxes, total spending, investment spending, operational spending, water spending, infrastructure spending, housing spending, education spending, and health spending. We merged these data with annual coffee prices and county-level coffee cultivation in 1980.

Because data on alcohol and tobacco tax revenue are also relevant to our analyses but are generally not reported at the county level, we also obtained department-year-level alcohol and tobacco tax revenue data for the years 1990–

2001 as well. We then merged these department-year data with department-level coffee cultivation measures from the 1980s and annual internal coffee prices.

NFCG: Social Contribution Spending

At our request, the NFCG has assembled historical information on its annual social contribution for 16 departments (or states) from 1979 to 2006. This data set represents the first time that the NFCG has assembled historical information on social contributions from its archival records. Instead of paying taxes, the NFCG makes these social investments to improve quality of life in rural coffee-growing regions of Colombia. These funds are generally spent on public goods for coffee growers, including agricultural research, business development, and publicity as well as four major areas of infrastructure investment (electrification, school construction, water, and roads).

Total social contribution spending is available at the department by year level with the exception of two instances in which NFCG records report combined information for several of Colombia's most sparsely populated departments (because of the organization of NFCG cooperatives in the most remote areas). These two multidepartmental units are (1) Caquetá, Casanare, Meta, and Chocó and (2) Cesar and La Guajira. Our results are insensitive to conducting aggregate regional-level analyses and to excluding these departments. Departments for which the NFCG reported no social spending are assumed to be missing (rather than reflecting no spending) and are omitted from our analyses. We aggregated our county-level coffee cultivation data to the department level and merged the department-year social contribution data with department-level coffee cultivation (using the immediately preceding coffee census) and annual coffee prices.

Colombian Vital Registry Records: Traffic Fatalities and Violent Deaths

Electronic death records at the individual level are available for the years 1979–2002 from DANE. These records include deaths by age, sex, cause (International Classification of Diseases), place of occurrence, place of residence, month and year, marital status, and certification by a medical professional. We provide graphical evidence of infant mortality over time by degree of coffee cultivation but do not generally otherwise make use of Colombia's mortality statistics because of concerns about data quality and underreporting (particularly given that the degree of underreporting is thought to be correlated with economic conditions; Flórez and Méndez 1997; Medina and Martínez 1999; Hill 2003). Appendix C provides indirect estimates of underreporting in Colombia's vital registry data that range between 30 percent and 45 percent. The exception is that we use DANE's county-year records of traffic fatalities and violent deaths (given that no alternative measure of these deaths is available) in investigating potential alternative explanations for the patterns of procyclical mortality that we observe.

Appendix C

Indirect Mortality Estimation

To assess the extent of underreporting in Colombia's mortality statistics, table

TABLE C1
Infant Mortality Underreporting in Colombia: Indirect Brass-Trussell Estimates versus Official Figures

Source	Year	Estimated Infant Mortality Rate	Vital Registry Infant Mortality Rate
DHS 1986	1986	40.6	27.9
DHS 1990	1990	37.5	20.0
DHS 1995	1995	33.7	18.0
DHS 2000	2000	30.6	17.1

Source.—Vital registry infant mortality data are from DANE; indirect Brass-Trussell infant mortality rate estimation procedures using the DHS waves (1986, 1990, 1995, and 2000) are described in App. D.
Note.—Rates shown are deaths under age 1 per 1,000 live births.

C1 shows indirect estimates of Colombia's infant mortality rate (deaths under age 1 per 1,000 live births) over time. These calculations, taken from Urdinola (2004), are conducted using Colombia's DHS and the Brass-Trussell method (United Nations 1990). Specifically, these estimates suggest that underreporting rates were 31 percent in 1986, 46 percent in 1990, 47 percent in 1995, and 44 percent in 2000. Similar calculations (not shown) using the Palloni-Heligman (1985) variant of the Brass method yield infant mortality estimates that are roughly equivalent. Table C1 suggests that the quality of Colombia's vital registration system may have been deteriorating over time. This is consistent with observations made by others assessing the quality of Colombia's vital registration system (Medina and Martínez 1999).

Indirect Estimation of Infant Mortality Rates: The Brass-Trussell Method[29]

The Brass method of indirect mortality estimation is a standard tool used by demographers to calculate the probability that a child has died ($q(x)$) by age x in cross-sectional data (Brass 1974). These probabilities $q(x)$ can therefore be interpreted as age-specific mortality rates commonly found in standard life tables. At a minimum, this method requires information on the proportion of infants and children who have died as a share of children ever born to women at each age. Widespread reliance on the Brass method in producing indirect estimates of age-specific mortality rates has led the United Nations to place the number of children ever born and the number of surviving children on its list of recommended items for national population censuses (United Nations 1990).

The Brass method essentially utilizes differences in child survival rates across age cohorts of mothers to recover information about age-specific child mortality. It exploits the fact that, all else equal, children (both alive and dead) born to older women are observed at older ages. Women at varying ages are therefore assumed to provide information about the experiences of all women in the population at each age. An important limitation of this approach is therefore its assumption that cumulative mortality rates depend on age alone. Never-

[29] For more details on indirect mortality estimation, see United Nations (1983, 1990) or Preston, Heuveline, and Guillot (2001).

theless, a large literature in demography demonstrates its usefulness as an approximation in assessing the extent of underreporting in vital registries.

Following standard notation used in demography, the numbers of children dead as a share of children ever born (denoted as D_i) among women in reproductive age groups i ($i = 1$ for women 15–19, $i = 2$ for women 20–24, …, $i = 7$ for women 45–49) are transformed into probabilities of dying ($q(x)$) between birth and exact age x. For the infant mortality calculations shown in table C1, the age x of interest is 1. The Brass method's basic equation is

$$q(x) = k_i D_i, \tag{C1}$$

where k_i is a vector of multipliers derived from fertility measures among women in the population of interest. Through simulations, Brass generated the proportions of children dead, the probabilities of dying, and parity ratios (P_1/P_2, P_2/P_3, etc.) linking them. Thus, an estimate of the probability of dying by age 1, $q(1)$, can be derived from the proportion of children dead reported by women aged 15–19, $D(1)$; the probability of dying by age 2, $q(2)$, can be obtained from the proportion of children dead for women aged 20–24, $D(2)$; and so on.

The original Brass method also assumes that mortality rates are constant over time, making cohort and period mortality probabilities identical. This assumption has subsequently been relaxed: if the rate of change over time is assumed to be constant, the reference date of each $q(x)$ can be estimated by making allowances for the age pattern of fertility by means of the parity ratios.

More flexible variants of the Brass method have also been developed. One of the best known is the Trussell (1975) variant, which estimates the multipliers k_i differently. Specifically, the fertility schedule used to produce the ratios P_1/P_2 and so on is taken from the Coale-Demeny (1966) model life tables.[30] The Trussell variant also differs in assuming that both infant mortality and fertility patterns remained constant in preceding periods (specifically, the preceding 15 years). Finally, the Palloni-Heligman variation includes a correction using more precise information on birth timing and employs United Nations model life tables for developing countries.[31] The Coale-Demeny model life table that best fits Colombian vital patterns is the West life table, and the Palloni-Heligman table that best fits Colombian vital patterns is the Latin American variant.

Appendix D

Informal Validity Tests

In this appendix we consider threats to the internal validity of this paper's main analyses. Any confounding influence must have varied in a very specific way—both over time in the same abrupt manner as birth year coffee prices and across counties in proportion to the intensity of birth county coffee cultivation. The most natural concerns are (1) that we mistake changes in the composition of

[30] Coale-Demeny model life tables were developed using data from a variety of countries and have for basic regional variants: North, South, East, and West.

[31] United Nations model life tables are also constructed for different regions of the world, with several distinct variants: Chilean, Latin American, South Asian, Far Eastern, and general.

TABLE D1
COFFEE PRICE SHOCKS, MATERNAL CHARACTERISTICS, AND BIRTH TIMING

	1975 Brazilian Frost	1985 Brazilian Drought	1990 ICA Collapse
Mother's age	.020	5.616	−.004
	(.016)	(17.600)	(.011)
Maternal education	−.009	.001	.004
	(.008)	(.009)	(.009)
Number of household members	−.005	−.003	−.009
	(.006)	(.010)	(.009)
Mother's preceding number of births	.003	−.011*	.001
	(.008)	(.006)	(.006)
Mother's age at first birth	.009	−.009	−.013
	(.007)	(.010)	(.016)
Mother's age at first marriage	.007	−.005	−.004
	(.010)	(.011)	(.034)
Preceding birth interval	−.026	.097	−.230
	(.074)	(.180)	(.204)

SOURCE.—Individual-level maternal characteristics are from the pooled 1986, 1990, 1995, and 2000 Colombian DHS child sample; coffee cultivation data are from the NFCG's early 1980s coffee census; and annual internal coffee price data are from the NFCG.

NOTE.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and coffee price in the year that a woman gave birth are obtained by estimating eq. (2) (controlling for county and year fixed effects and county-specific linear trends). Coffee area is in hundreds of hectares and coffee prices are in hundreds of pesos per kilogram.

* $p < .1$.
** $p < .05$.
*** $p < .01$.

births or women giving birth for mortality responses or (2) that selection into areas with varying coffee-growing intensity biases our main results. This appendix presents validity tests that investigate—but fail to corroborate—these concerns.

We first consider how coffee price shocks might alter the composition of births or the types of women giving birth. Economic models of fertility predict that changes in economic circumstances should differentially influence the fertility of women with varying opportunity costs of time (e.g., as measured by socioeconomic status; Becker and Lewis 1973; Ben-Porath 1973; Butz and Ward 1979; Becker 1981; Perry 2003; Dehejia and Lleras-Muney 2004). As already described, we address potential changes in the composition of women giving birth by restricting our analyses to children already conceived at the time a price shock occurred (children born in shock years or earlier). However, because we know only children's year of birth, we also investigate the possibility of confounding compositional changes directly. Exploiting detailed information on maternal characteristics available in the DHS, we use the pooled the survey's sample of children aged 0–2 in price shock years to regress measures of maternal socioeconomic status on the interaction between birth year coffee price and birth county coffee cultivation as in equation (2).

Table D1 shows coefficient estimates for the interaction between coffee price and intensity. There is no evidence of any change in the composition of mothers' age, education, age at first birth, age at first marriage, preceding number of births, or number of household members. Similarly, estimates for preceding birth intervals—a direct measure of fertility—are statistically indistinguishable

TABLE D2
CPI Changes and ln(Cohort Size) in Stable Coffee Price Years

	Sample/Specification		
	Ages 0–2	Ages 0–3	Ages 0–3 with Trends
	A. 1969 CPI Change		
Estimate	−1.91	−.04	7.79
	(1.21)	(.66)	(5.95)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Observations	2,207	3,314	3,314
R^2	.99	.99	.99
	B. 1983 CPI Change		
Estimate	−1.10	−.83	.07
	(.70)	(.53)	(.05)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Observations	2,207	3,310	3,310
R^2	.99	.99	.99
	C. 1989 CPI Change		
Estimate	−.01	.00	−.08
	(.01)	(.00)	(.09)
County fixed effects	Yes	Yes	Yes
County-specific linear trends	No	No	Yes
Observations	2,204	3,305	3,305
R^2	.99	.99	.99

Source.—County-year cohort size data are from the complete 1993 Colombian population census; coffee cultivation data are from the NFCG's early 1980s coffee census; and annual CPI data are from the Central Bank of Colombia.

Note.—Estimates and standard errors (in parentheses, clustered by county) shown for the interaction between coffee-growing intensity and CPI in the first year of life are obtained by estimating eq. (1) (controlling for county and year fixed effects and county-specific linear trends as shown above). Coffee area is in hundreds of hectares and coffee prices are in hundreds of pesos per kilogram.

from zero. Other confounding compositional changes should be detectable in these analyses as well—including differential migration of pregnant women induced by price shocks and selective mortality among women giving birth—but we find little evidence of them.

We then explore how selection into counties with varying coffee-growing intensity prior to price shocks might bias our cohort size results. Although we are able to condition our estimates on both fixed and time-varying differences across counties, Colombians might sort themselves into counties with varying coffee-growing intensity according to unobserved latent characteristics related to price responsiveness and child survival that become manifest in the presence of price shocks. A testable implication of this concern is that if people in counties with varying coffee-growing intensity were subjected to the same price shock (i.e., one whose impact should not vary with coffee-growing intensity), they would respond differently in ways related to infant and child survival.

To test this concern, we replace internal coffee prices with the Colombian consumer price index (CPI) and reestimate equation (1) using stable coffee price years (1968–69, 1982–83, and 1988–89). During these years, Colombian consumer prices changed by 7 percent, 20 percent, and 26 percent, respectively.[32] Table D2 presents coefficient estimates for the interaction between birth year CPI and coffee-growing intensity. None are statistically distinguishable from zero.

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[32] See http://www.banrep.gov.co/econome/dsbb/i_srea_012.xls.

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