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Hedging with Futures Contracts by Developing Countries: Empirical Evidence

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This paper attempts to evaluate the benefits that Less Developed Countries (LDCs), subject to price and quantity fluctuation of its exports (of one or several commodities) may derive from using futures markets. The Ivory Coast was chosen to illustrate our analysis. Three products (cocoa, coffee and cotton) are studied in order to take into account the weight of exports revenues in the whole economy, the effect of variability, the role of the Caisse de Stabilisation et de Soutien des Prix des Produits Agricoles (CSSPPA: A National Marketing Board) and the gains from using futures markets as the hedging tool relative to stabilizing policies.

I. Introduction

Less Developed Countries (LDCs) primary commodity exporting countries face fluctuating prices for their exports. Except possibly for a few large producers, these fluctuating prices translate into fluctuating revenues. For many LDC producers, particularly those in the middle range of *per capita* incomes, receipts from non-oil primary exports are the major source of foreign exchange. Many of the same countries are very heavily in debt. For such countries, a fall in export earnings forces a fall in foreign exchange expenditures. This may take the form of a fall in living standards, as imports of luxuries or even basic foodstuffs either become very expensive or are prohibited, or of a fall in investment expenditure, including maintenance. Either way the country suffers.

In the short run, commodity exporting countries face the risk of

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large economic losses have come through commodity traders profiting from the divergences between official and informal, but available, foreign exchange rates. Less well known but equally significant trading problems have emerged when real interest rates in these countries have been kept above those paid on the world market — which has allowed commodity traders to earn more from financial transactions than from commodity trading. And counter-trade deals are notorious for the cost premium that results from the risk of large and unpredictable losses when the products offered in exchange for commodity exports are disposed of.

If developing countries have not generally been succesful in adjusting to the new situation in commodity markets, there remains evidence that all is not bleak. Both multinational companies as well as primary product producers in developed economies, have had to cope with precisely the same sorts of problems. Initially, their performance was no better than that of their counterparts in the developing world; but over recent years, the multinationals have adapted their financial management strategies so as to acquire greater protection — against the new forms of uncertainty in commodity markets (both in primary product and in monetary prices). In the process, they have discovered that long-term fixed price deals across national boundaries are often impossible to enforce. They have also learnt the hard way that sudden fluctuations in interest rates, exchange rates, raw material costs and selling prices are all critical determinants of any new investment and viability.

As a result, the use of various financial instruments for managing commodity price risks has increased exponentially since the early 1970s. Increased use has allowed many possible pitfalls to be recognized early and enabled corrective action to be taken in good time, thereby engendering greater reliability of these instruments. This in turn, has encouraged others to use them while stimulating the introduction of new, tailor-made futures or options contracts, as well as a proliferation of insurance products. While many of the specific applications are new, the various tools for better trading now in common use have all been applied by specialists for the past hundred years.

Thus, although the techniques of "hedging," "basis pricing," "spread trading" or "rolling over futures contracts" may seem somewhat arcane to those unfamiliar with them, there is in fact a great deal of experience in how these various price risk management tools perform under wide variety of conditions. One of the more dramatic changes in the world financial system in the last few years has been the application of options and futures contracts, which were originally used in conjunction with trading primary commodities such as wheat or copper, to the "new"

For commercial reasons, the producer may choose a vector of positions (f) on the futures markets. Let f_i be the size of the long position in the i'th futures that the producer opens at time 0. (A short position is represented if $f_i<0$). The position f_i will be closed out at date t ($t \leqslant t_1$) by an offsetting trade. The offsetting transaction may be financial or physical. In t_o, futures prices (for futures contracts which will be delivered at t_1) are quoted on futures markets and represented by the vector P_o^f.

Usually the offsetting operation are made by a financial transaction in t ($t<t_1$) consisting of a purchase of f_i (if $f_i<0$) or a sale of f_i (if $f_i>0$) at P^f_t. Let P^f_t be the random n column vector of the i'th futures that prevails at time t.

A time 0 the period 1 prices are random variables $\tilde{P}$ and $\tilde{P}_1^f$ for which the producer has a joint subjective probability distribution. Let Σ be the variance/covariance matix of $(\tilde{Y}, \tilde{p}, \tilde{p}_1^f)$ which we partition as,

$$\Sigma = \begin{bmatrix} \Sigma_{11} & \Sigma_{12} & \Sigma_{13} \\ \Sigma_{21} & \Sigma_{22} & \Sigma_{23} \\ \Sigma_{31} & \Sigma_{32} & \Sigma_{33} \end{bmatrix}$$

where $\Sigma_{33} = \mathrm{Var}\,(\tilde{P}_t^f)$ is symmetric and positive definite.

With this notation the producer's period 1 revenue is the random variable,

$$\begin{aligned} (2.1) \quad \tilde{R} &= \tilde{p}'\,\tilde{Y} - (\tilde{P}_1^f - P_0^f)'f \\ &= \tilde{R}_c - (P_1^f - P_0^f)'f \text{ with } \tilde{R}_c = \tilde{p}'\tilde{Y} \end{aligned}$$

B. Data Preparation

For each product i (i = 1, 2, 3), R_i represents exports revenues. Export prices are represented by

$$P_i = \frac{R_i}{Y_i}$$

where Y_i is the volume of exports that occur each year.

P_i is an annual export price index. Data were collected from the United Nations Statistics. In the empirical framework the set P_i, R_i and Y_i are represented by (Pcoco, Pcof, Pcot); (REVcoco, REVcof, REVcot); and (VOLcoco, VOLcof, VOLcot) respectively for cocoa, coffee and cotton.

Four contracts were chosen for each commodity, in order to cover the policies. Through this section we try to answer to the question, how can the Ivory Coast rely on information given by futures prices to predict exports prices?

A way of responding to this question is to find the relationship that links the Ivory Coast's exports prices and futures prices and to assess its consistency.

Export prices has been regressed on futures prices for all commodities according to a simple linear model

$$I_{it} = \alpha + \beta P_{it}^{f} + \varepsilon_{it}$$

where I_{it} is the annual exports prices index of the Ivory Coast for commodity i

P_{it}^{f} is the annual futures prices for commodity t.

ε_{it} is the error term.

Parameters α and β are to be estimated. They convey information on the relationship that exists between I_{it} and P_{it}^{f}. Coefficients were estimated by Ordinary Least Squares (OLS). Student t tests were conducted at a 5% significance level to judge the significance of the coefficients. Results on estimations and tests are reproduced in Table 1. Tests confirm the hypothesis that futures prices explain the export prices of the Ivory Coast. So futures prices have information content: they may be useful for commercial policies of the Ivory Coast. Futures prices are unbiased predictors of cotton and coffee export prices, α and β are not significant different from 0 and 1 respectively.

IV. Estimating Optimal Futures Positions

Optimal positions may be derived according to two main hypotheses:

(i) First the producer may enter futures markets in search of insurance against export revenue risk (pure hedging)

(ii) Second the producer may trade futures in order to maximize his expected utility by hedging his export revenues and by speculating in spot and futures prices changes (hedging under utility maximization hypothesis.)

sider a hedger as a risk-avoider. The producer enters futures markets in order to minimize the risk usually represented by the variance of revenue. The effectiveness of his hedge may be represented by the maximum reduction of variance owing to the position he opens on futures markets. The producer's problem is then as follows: What position must he take in futures in order to minimize the variance of his revenues?

The variance of equation (2.1) is:

(4.1) $V(\tilde{R}) = V(\tilde{R}_c) + f'\Sigma_{33}f - 2\ \mathrm{Cov}\ (\tilde{R}_c,\ \tilde{P}_t^{f}{}' f)$

The domain of positions that reduce $V(\tilde{R}_c)$ is given by

(4.2) $V(\tilde{R}) \leq V(\tilde{R}_c)$ or $V(\tilde{P}_t^{f}{}' f) \leq 2\ \mathrm{Cov}\ (\tilde{R}_c,\ \tilde{P}_t^{f}{}'\ f)$.

The pure hedge is equivalent to the position that minimizes V(R).

$$\underset{f}{\mathrm{Min}}\ V(\tilde{R}) = V(\tilde{R}_c) + f'\Sigma_{33}f - 2\ \mathrm{Cov}\ (\tilde{R}_c,\ \tilde{P}_1^{f}.'\ f)$$

whose first order conditions are given by

$$\Sigma_{33}f - \mathrm{Cov}\ (\tilde{R}_c,\ \tilde{P}_t^{f}) = 0$$

Σ_{33} is a positive definite matrix, second order conditions are satisfied and we may derive the n pure hedges:

(4.3) $f_M{}^* = \Sigma_{33}{}^{-1} \cdot \mathrm{Cov}\ (\tilde{R}_c,\ \tilde{P}_t^{f})$

$f_M{}^*$ determines a minimum value of $V(\tilde{R})$. Johnson (1960) and Ederington (1979) derived the same result in a particular case (n = 1 and Y certain); Mckinnon (1967) found a similar result in the case of n = 1 and Y variable. Pure hedge may be derived by estimating the coefficients of elements of $\tilde{P}_t^{f}$ in the theoretical multiple regression of $\tilde{R}_c$ on $\tilde{P}_t^{f}$.

Effectiveness of such a strategy can be derived by comparing the risk of an unhedged revenue $V(\tilde{R}_c)$ with the minimum risk that can be obtained by means of a pure hedge $V(R(f_c{}^*))$, where $V(R(f_c{}^*))$ is $V(\bar{R})$ of equation (4.1) when f equal $f_c{}^*$.

Let us define the effectiveness of pure hedging (μ) by its maximum reduction in variance or in other terms by the percent reduction in variance (Johnson (1960), Ederington (1979), Overdahl (1984)). We may write:

Results are grouped in Table 2. The first feature of pure hedges is that they are all positive (short positions). Futures positions are relatively small for cocoa, high for coffee and very high for cotton. Pure hedge ratios (δ_c*)

Table 2

RESULTS OF PURE HEDGING: COMMODITY BY COMMODITY

	Delivery	f_c*	δ_c*	π	Y*	μ	d	d*
	March	25,164	12.60%	-0.411*		32.10%	1,058*	0.50%
		(2.57)		(-0.72)		< 3.76 >	(0.15)	
	May	25,723	12.90%	-0.235*		27.7%*	2,519*	1.20%
		(2.31)		(-0.36)	199,613	< 3.11 >	(0.33)	
COCOA	July	17,507*	8.80%	-0.909*		18.08*	3,990*	2.00%
		(1.75)		(-0.86)		< 1.76 >	(0.63)	
	Sept.	20,341*	10.20%	-1.207*		22.3%*	3,606*	1.80%
		(2.00)		(-1.30)		< 2.26 >	(0.54)	
	March	110,032	44.20%	-0.358*		63.80%	19,293*	7.80%
		(3.76)		(-1.14)		< 7.11 >	(1.36)	
	May	131,051	52.70%	-0.428*		78.20%	16,646*	6.70%
		(5.36)		(-1.57)	248,743	< 14.18 >	(1.05)	
COFFEE	July	137,344	55.20%	-0.354*		87.80%	10,166*	4.10%
		(7.59)		(-1.08)		< 29.33 >	(0.62)	
	Sept.	173,682	69.80%	-0.417*		95.20%	-2,702*	-0.011
		(12.65)		(-1.38)		< 76.0 >	(-0.13)	
	March	38,524c	185.20%	0.033*		65.00%	19,445	-0.935
		(4.91)		(0.699)		< 12.07 >	(-2.78)	
	May	42,080**	202.30%	0.004*		67.70%	-21,594	-1.038
		(5.22)		(0.076)	20,805	< 13.81 >	(2.96)	
COTTON	July	39,482c	189.80%	-0.001*		60.50%	-19,947	-0.959
		(4.46)		(-0.002)		< 9.75 >	(-2.64)	
	Oct.	31,465c	151.20%	-0.064*		44.20%	-16,494	-0.793
		(3.20)		(-0.55)		< 50.11 >	(-2.21)	

At a 5% level:

* We cannot reject the hypothesis that they are equal to zero (pure hedge ratio, gain, hedge effectiveness, variablity effect)

** We cannot reject the hypothesis that $\delta_c^* = 2$ (= 200%)

c We cannot reject full hedge hypothesis ($\delta_c^* = 1$) = ($\delta_c^* = 100\%$)

d* = d/y*

π = $E(p_0^f - p_1^f)$; positive π corresponds to unity gain on futures and unity gain on futures and a loss on the country.

Numbers in parentheses are "computed t"; those in < > are F values.

Table 3

CORRELATIONS MATRIX

3.1. Correlations matrix (export prices)

	Pcoco	Pcof	Pcot
Pcoco	1.0		
Pcof	0.88	1.0	
Pcot	0.49	0.46	1.0

3.2. Correlations matrix (volume of exports)

	VOLcoco	VOLcof	VOLcot
VOLcoco	1.0		
VOLcof	–0.21	1.0	
VOLcot	0.84	–0.20	1.0

3.3 Correlations matrix (exports revenues)

	REVcoco	REVcof	REVcot
REVcoco	1.0		
REVcof	–0.54	1.0	
REVcot	0.85	0.33	1.0

(4.8) $REV_{tot} = \alpha + \beta P_t^f + \varepsilon_t$

Where REV_{tot} = REVcoco + REVcof + REVcot and P_t^f the vector of future prices in time t. Estimated β are pure hedges and μ was estimated by the R^2 coefficient of (4.8) the results are exhibited in Table 4. The suggested optimal strategy is an over-hedge for coffee, a hedge ratio of more than 70% for cotton and a small position for cocoa (not more than 5%). Such position support the prospect of reducing the global risk by 81% as index μ indicates.

C. Hedging Under Utility Maximization Hypothesis

The traditional definition of hedging (KEYNES, 1930; HICKS, 1946; HIERONYMUS, 1971) considers hedging as searching for insurance in

Table 5

OPTIMAL HEDGING GAINS IN TERMS OF
AVERAGE EXPORT REVENUES OF THE IVORY COAST

Good	Futures	μ	Gr (in %)
	March	0.32	10.6
	May	0.28	9.2
COCOA	July	0.18	6.0
	Septmber	0.22	7.3
	March	0.64	5.6
	May	0.78	6.8
COFFEE	July	0.88	7.7
	September	0.95	8.3
	March	0.65	20.4
	May	0.68	21.3
COTTON	July	0.60	18.8
	October	0.44	13.8

Results are derived under hypothesis of a utility function of BERNOULLI (1938) ($\alpha' = 1$).

where α is the Arrow — Pratt measure of absolute risk aversion coefficient. E is the expectation operator. The second part of (4.9) is the measure of risk premium at $E(\tilde{R})$ level.

Necessary conditions of a maximum are given by:

$$(4.10) \quad (P_o^f - E(\tilde{P}_f)) - \alpha(\Sigma_{33}f - \text{Cov}\ (\tilde{R}_c,\ \tilde{P}_f)) = 0.$$

These necessary conditions are also sufficient given the concavity of $U(\cdot)$. As Σ_{33} is a positive definite matrix we may derive optimal positions:

$$(4.11) \quad f^* = 1/\alpha\ \Sigma_{33}^{-1}\ (P_o^f - E(\tilde{P}_f)) + \Sigma_{33}^{-1}\ (\text{Cov}(\tilde{R}_c,\ \tilde{P}_f))$$

Optimal hedge f^* is formed by two parts:

a) $1/\alpha\ \Sigma_{33}^{-1}\ (E(\tilde{P}_f) - P_o^f)$ is the optimal position of an operator whose physical position equals zero ($Y = 0$). Such an operator is called a "Speculator."

   This position depends on the subjective futures price probability distribution and on risk aversion. It tends to zero as the absolute risk aversion coefficient tends to infinity. It vanishes when the vector of gains on futures:

Proof:

a) According to (4.11) the optimal hedge when production is known is given by quantities

(5.2) $f^*_1 = \Sigma_{33}^{-1} \, (1/\alpha \, (P_{o}f) - E(\tilde{P}f) + \text{Cov} \, ((\tilde{P}'Y, \, \tilde{P}f))$

b) When production is stochastic, optimal positions are given by f* of (4.11).

Let d be the differnce between optimal positions of non-variable and variable productions. We then have:

(5.3) $d = f^*_1 - f^*$

Substituting f^*_1 and f^* by their respective values of (5.2) and (4.11) in (5.3) we get

(5.4) $d = \Sigma_{33}^{-1} \, (\Sigma_{23} \, (Y) - \text{Cov} \, (\tilde{R}_c, \, \tilde{P}_f))$

Thus we may claim that production variability reduces optimal positions (5.2) if and only if $d > 0$ which means:

$$\Sigma_{33}^{-1} \, (\Sigma_{23} \, Y - \text{Cov} \, (\tilde{R}_c, \, \tilde{P}_f)) > 0.$$

Vector d is the measure of the absolute effect of production variability on optimal positions. It is worth observing that the pure speculation terms of (4.11) and (5.2) vanished. *So d is only the difference of pure hedges.* This result is intuititive for speculation components and are independent of production Y. Production variability may exercise its effect only on a pure hedges. Such an effect may be negative as well as positive depending on the probability distribution of prices and quantities. However production will not always have an effect on optimal hedge as is stated by the following proposition:

Proposition 2

When production Y is variable but independent of futures and spot prices, its variability has no effect on optimal position ($d = 0$). This is derived from the statistical statement that

(5.5) $\text{Cov} \, (x \, y, \, z) = \text{Cov} \, (xE(y), \, z)$

(6.1) $W(f^*) > W(O)$

in virtue of strict monotonicity of u ( ). This approach is compatible with the theory of choice by a risk-averse agent under uncertainty (STIGLITZ, 1981). This is the same as stating that $R(f^*)$ dominates R_c for a risk-averse agent.

From (4.9) we may write:

$$(6.2) \qquad W(O) = E(\tilde{R}_c) - \frac{\alpha\, V(\tilde{R}_c)}{2} \text{ (without using futures)}$$

$$W(f^*) = E(\tilde{R}) - \frac{\alpha\, V(\tilde{R}(f^*))}{2} \text{ (using futures)}$$

where second terms are risk premia.

The gains from using futures markets are $G = W(f^*) - W(O)$ and

$$(6.3) \qquad G = (E(\tilde{p}_f) - p_o f)' f^* + \frac{\alpha(V(\tilde{R}_c) - V(\tilde{R}(f^*)))}{2}$$

B. Gains from Price Stabilization Policies

Here we adopt a measure of computing gains from price stabilization policies as derived by NEWBERY and STIGLITZ (1981). The method consists in finding a sum of money a producer would be willing to pay for a stabilization scheme to be introduced. Efficiency or risk benefit to the producer is

$$(6.4) \qquad Br = 1/2\ R\Delta\sigma^2_y$$

where R = the relative risk-aversion coefficient
$\Delta\sigma^2_y$ = change in the square of coefficient of variation of the revenue.

Risk benefits were computed for various countries (and commodities) for period 1951-1975. Results are reproduced in Table 6. The *risk benefits (cocoa and coffee) for Ivory Coast are small.*

C. Comparing Gains

To analyse the futures performance for the Ivory Coast in terms of $E(R_c)$ we computed G for various commodities. We first show that G is similar to the NEWBERY and STIGLITZ Br, and second we compare computed G and Br.

We can write (6.3) as follow:

$$(6.5) \qquad G = \frac{\alpha(V(\tilde{R}_c) - V(\tilde{R}(f^*)))}{2}$$

$$(6.7) \qquad G = \frac{R^* \ \alpha(V(\tilde{R}_c) - V(\tilde{R}(f^*)))}{2R^*} = \frac{\alpha' \ \Delta V}{2R^*}$$

R^* = Average income, proxy of $E(\tilde{R}_c)$
α' = $(\alpha\, R^*)$ = relative risk-aversion coefficient (level R^*)
ΔV = absolute reduction of variance by optimal hedging f^* $(V(\tilde{R}_c) - V(R(f^*)))$ of $\tilde{R}_c$

$$(6.8) \qquad G = \frac{\alpha' \ \Delta V R^{*2}}{R^* \ 2R^{*2}} = \frac{\alpha' \ \Delta v^2 \ R^*}{2}$$

with $\Delta v^2 = (\Delta V / R^{*2})$ = absolute change in the square of coefficient of variation of $\tilde{R}_c$.

$$(6.9) \qquad Gr = \frac{G}{R^*} = \frac{\alpha' \ \Delta v^2}{2}$$

which corresponds to Br of (6.4) the risk benefit as derived by NEWBERY and STIGLITZ. In fact both Br and Gr express the same reality and become comparable. They may be defined as the net prime of risk or the maximum amount (in terms of expected revenue) a risk-avoider producer is willing to pay for risk reduction (by a stabilization scheme or by hedging on futures markets).

Effectiveness of pure hedge or maximum reduction of variance of R_c by hedging was computed as:

$$\mu = (\Delta V / V(\tilde{R}_c)) \quad \text{in } (4.4)$$

Substituting (4.4) in (6.9) we get:

cy hedge in addition to the commodity hedge; he must decide in which month or months to take a position and when to roll forward; and he must be alert to movements in the temporal basis which will make maintenance of the hedge disadvantageous. Few LDC producers will have employees with these skills, and if they are to exploit the potential of the futures exchanges they must either invest in training or recruit skilled traders in the developed economies. In general, they will be well advised to do both of these, but this may require encouragement by the exchanges and other sympathic organization.

(ii) LDC producers and governments frequently lack the financial and management expertise necessary to exploit futures trading opportunities. It is obviously true that individual farmers of peasant products will be unable or unwilling to acquire the required level of expertise, but problems may also exist at the level of the state trade corporation or export ministry. However, experience in a number of commodities suggests that, it is unnecessary for producers to acquire the expertise. The predominant marketing arrangement in these trades is for producers to sell to commodity dealers than to hedge their positions on the futures markets. This form of marketing arrangement is a great deal simpler for management in the producer country, and can yield all the disadvantages of direct futures markets trading.

(iii) LDC producers may be discouraged from taking futures positions because of the difficulty in obtaining finance, and in particular foreign exchange, to cover the payment of variation margins.

VII. Conclusion

This paper shows how producing LDC's subject to price and quantity fluctuations may use futures prices to predict its export prices and hedge its exports revenues on futures markets. The Ivory Coast was chosen for the study. First it appears to be a suitable representative of commodity exporting LDC's whose economies are sensitive to changes in export earnings. Indeed the Ivory Coast founded its development on exports. The information performance of futures markets was tested. The result is that futures prices predict rather well exports prices of the Ivory Coast.

Optimal positions were derived and estimated for cocoa, coffee and cotton under hypothesis of risk minimization (pure hedge) and expected utility maximization. Generally the full hedge hypothesis was rejected at a 5% level. Optimal hedge ratios are considerable and such hedges are effective. (except for cocoa). Risk of exports revenues could be reduced by hedging is only likely to be available on attractive (i.e. efficiently priced) terms if the contracts are fungible.

Appendix

DEMONSTRATION of: If Y is independent of P and P^f_t then d = 0. Let us prove proposition 2 for the case n = 1 and replace variables P, Y and P^f_t respectively by x, y and z.

Variable y is independent of x and z if and only if

(A.1) f(x,y,z) = f(x,z) f(y) where f( ) is the joint density function of x,y and z
Cov (xE(y), z) = E(y)Cov (x,z)

We have to prove that Cov (xy,z) = E(y) Cov (x,z)

$$\text{(A.2)} \quad \text{Cov}(xy,z) = \int_{xy,\,z} (xy-E(xy))(z-E(z))\, f(x,z).f(y)dxdydz$$

$$= \int_y y \left(\int_{xz} x(z-E(z))f(x,z)\, dxdz\right) f(y)dy$$

$$-E(xy) \int_y \left(\int_{xz} (z-E(z))f(x,z)\, dxdz\right) f(y)dy$$

$$\text{with} \int_{xz} (z-E(z))\, f(x,z)dxdz = 0$$

Then

$$\text{Cov}(xy,z) = \int_y y \left(\int_{xz} (x-E(x)+E(x))(z-E(z))f(x,z)dxdz\right) f(y)dy$$

$$= \int_y y \left[\int_{xz} (x-E(x))(z-E(z))f(x,z)dxdz + E(x) \int_{xz} (z-E(z))f(x,z)\, dxdz\right] f(y)dy$$

Then

$$\text{Cov}(xy,z) = \int_y y(\text{Cov}(x,z))f(y)dy$$

$$= \text{Cov}(x,z) \int_y y\, f(y)dy$$

$$= \text{Cov}(x,z)E(y)$$

and finally
Cov(xy,z) = Cov(xE(y),z) for y independent of x and z

So d = (Cov(PE(Y), P^f_t)–Cov(PY, P^f_t) = 0 for Y independent of P and P^f_t.

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