The theory of storage

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Section 1. The analysis of contango and backwardation

Section 2. The convenience yield

Section 3. Empirical tests of the storage theory

Section 4. Critiques of the theory

Section 5. Conclusion

Section 1. The analysis of contango (F>S) and backwardation (F>S)

1.1. Arbitrage operations

1.2. The analysis of contango

1.3. Backwardation and convenience yield

1.1. Arbitrage operations

In the presence of surplus stocks

1) The level of contango can not stay higher than the storage costs

- Reason: Cash and carry operations
- If $F - S > C$

then:	buy at price S:	- S
	sell at price F:	+ F
	finance the storage costs:	- C
Result:		> 0

2. Backwardation is impossible:

- Reason: Reverse cash and carry operations
- If F < S

then:	sell at price S:	+ S
	buy at price F:	- F
	avoid the storage costs	+ C
Result:		>> 0

When physical stocks are low,

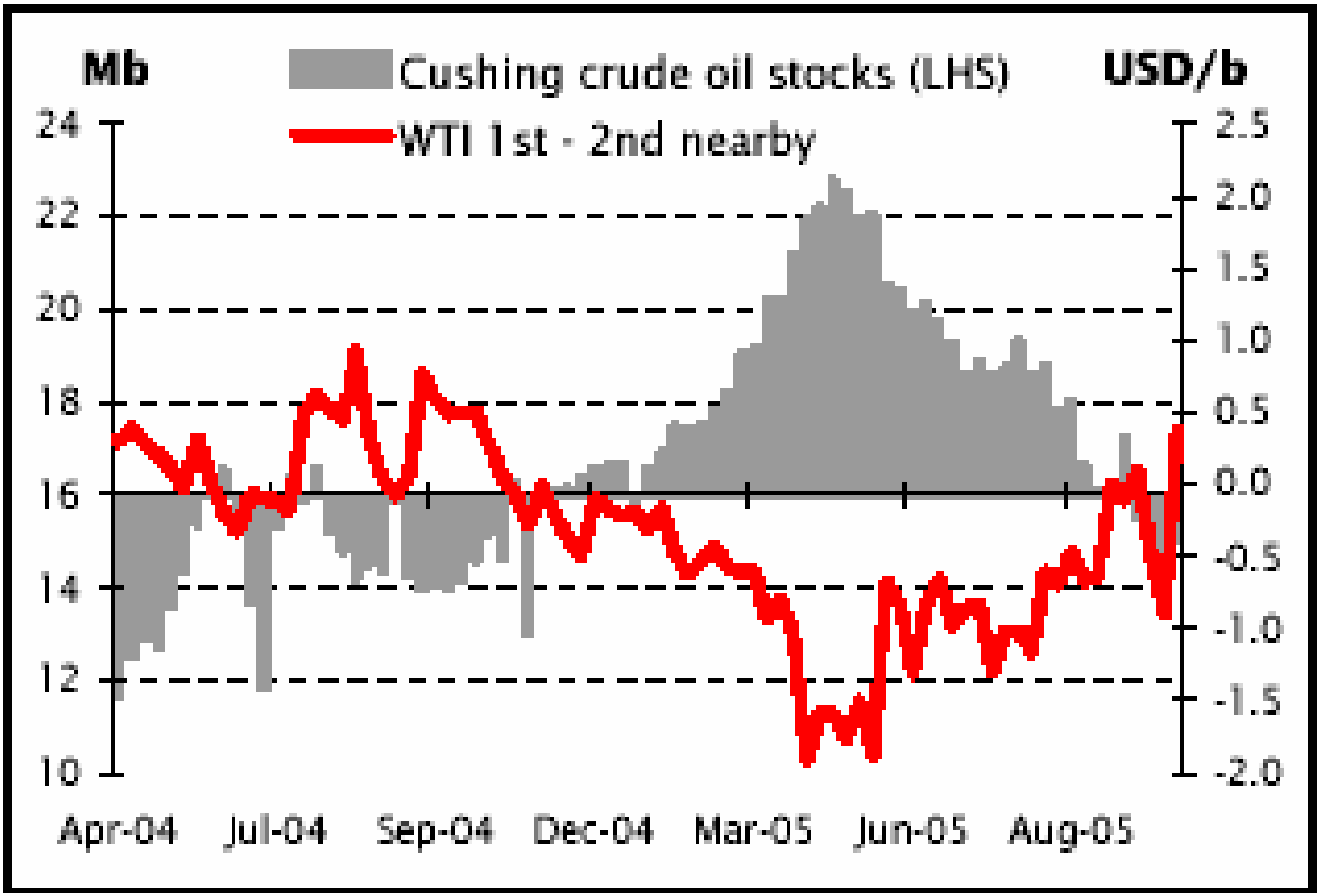
- There is backwardation
- Reverse cash and carry are unlikely to happen
- Consequence:

G. Blau, 1944-45:

«*Arbitrage can always be relied upon to prevent the forward price from exceeding the spot price by more than net carrying cost...*

[but] can not be equally effective in preventing the forward price from exceeding the spot price by less than net carrying cost.»

Crude oil stocks at Cushing vs. WTI 1st time spread



Source: US DOE Weekly, NYMEX & SG Commodities Research

- **In contango,**

  - the basis is stable (as long as storage capacities are not saturated)

  - it is limited to storage costs

- **In backwardation,**

  - the basis is not stable

  - it is determined by the spot price that operators are willing to pay: there is no objective limit to the basis

1.2. The analysis of contango (F(t,T)>S(t))

Storage costs (carrying charges):

- Deterioration and obsolescence
- Insurance costs
- Warehouse costs
- Financial costs
- Fluctuation of commodity prices

$$F(t,T) = S(t) + C_S(t,T)$$

1.3. Backwardation and convenience yield

- If the futures price is equal to the spot price plus positive storage costs, how can it become inferior to the spot price?
- N. Kaldor (1939-40):

*« In normal circumstances, stocks of all goods possess a **yield**, measured in terms of themselves,*

*and this yield which is a **compensation** to the holder of stocks,*

must be deducted from carrying costs proper in calculating net carrying cost.

The latter can, therefore, be negative or positive. »

$$F(t,T) = S(t) + C_S(t,T) - C_y(t)$$

Section 2. The convenience yield

2.1. Convenience yield and risk premium

2.2. Stock-out and coverage yields

2.3. Convenience yield, forward and futures contracts

2.1. Convenience yield and risk premium

- Brennan, 1958 : supply and demand of inventory

$$E_t\left[S(t+1)\right] - S(t) = CS_t(L_t) + \pi_t(L_t) - CY_t(L_t)$$

  - S(t): spot price,
  - CS_t: marginal storage cost,
  - L_t: inventory' level,
  - π_t: marginal risk premium on inventory,
  - CY_t: marginal convenience yield

M.J. Brennan, 1958 :

«The convenience yield is attributed to the advantage (in terms of less delay and lower costs)

of being able to keep regular customers satisfied

or of being able ***to take advantage of a rise in demand and price***

without resorting to a revision of the production schedule.»

2.2. Stock-out yield and coverage yield

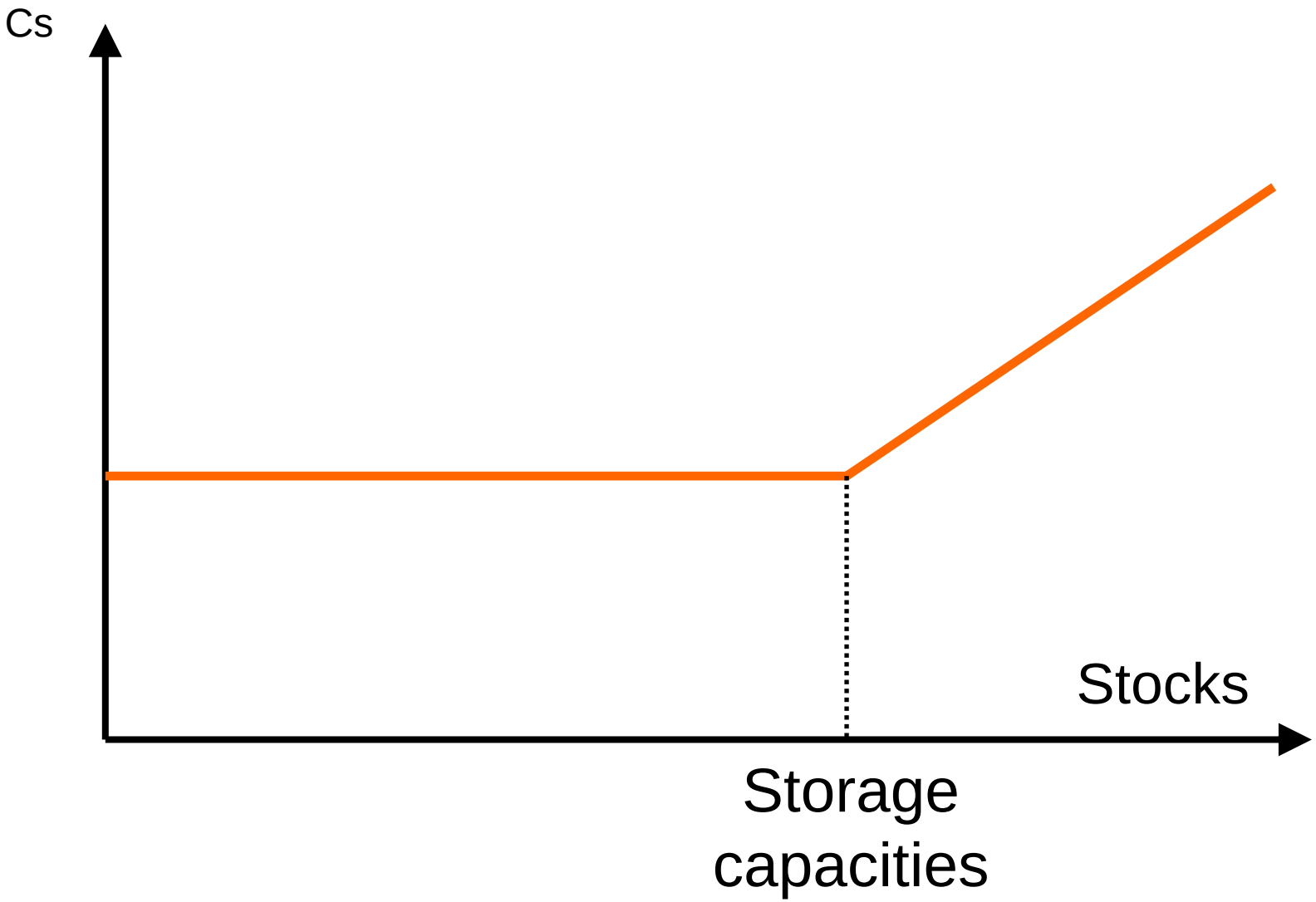
Marginal inventory holding costs depend on:

Pure storage costs

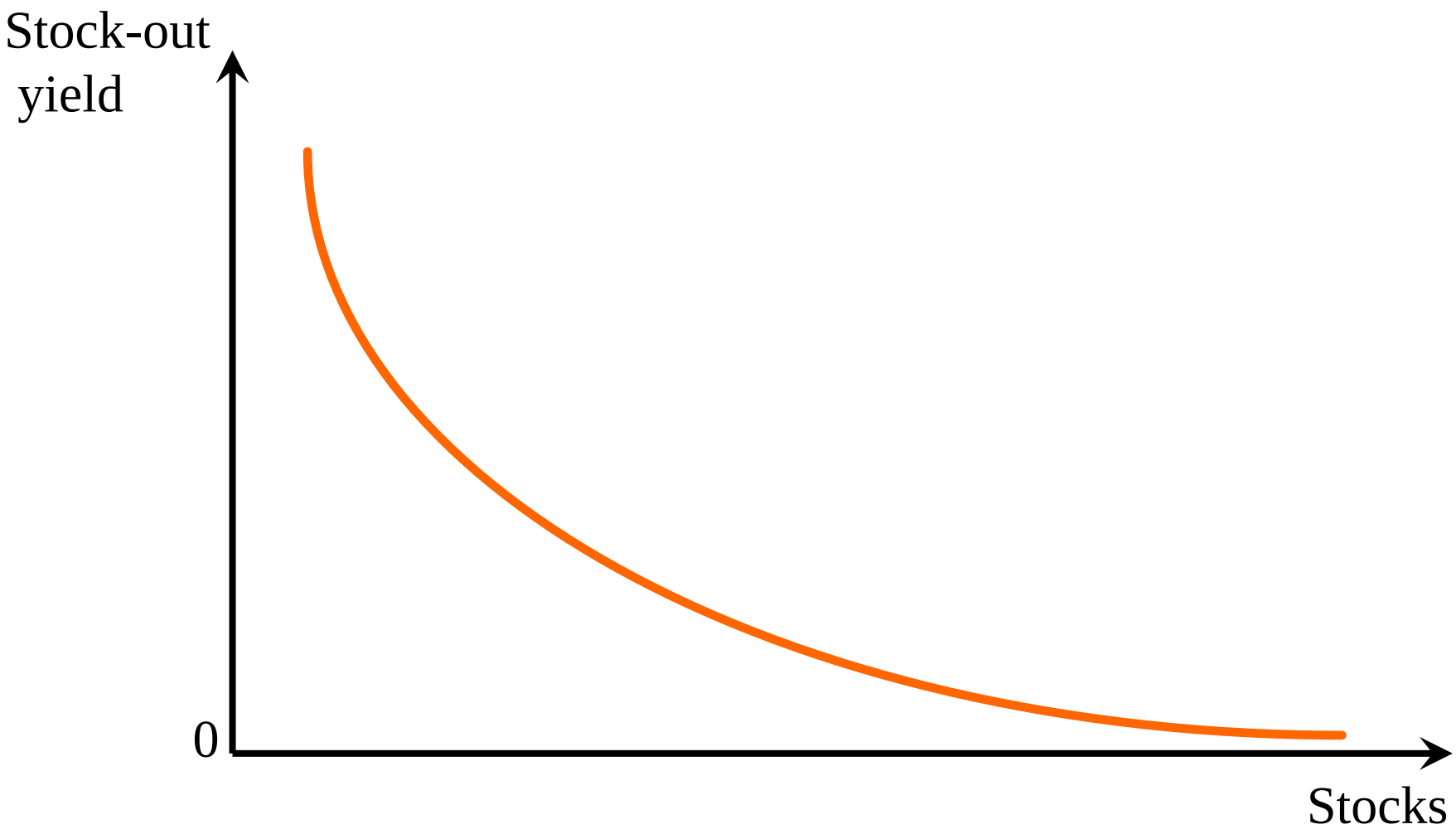
Stock-out yield

Coverage yield

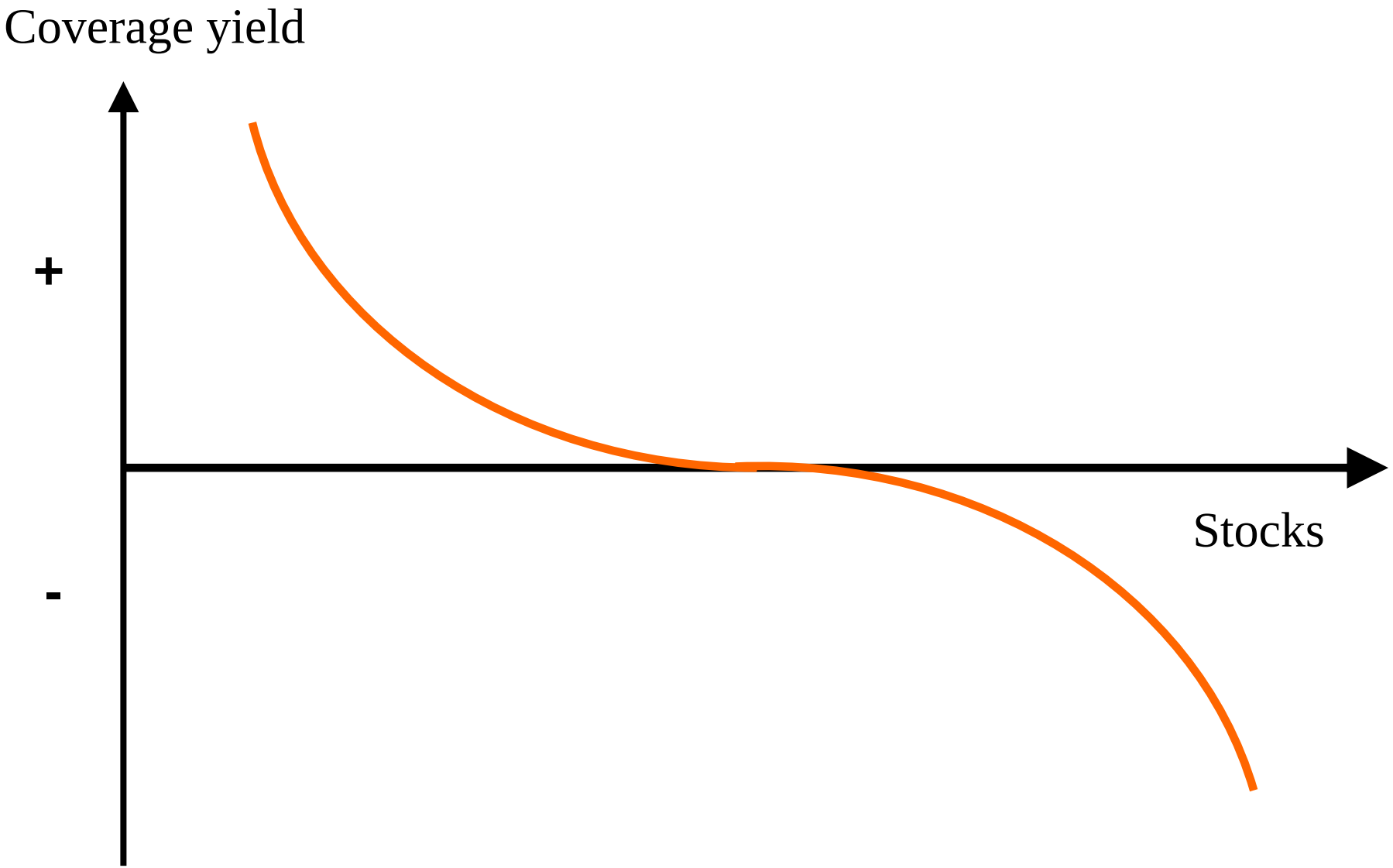
Pure storage cost



Stock-out yield



Coverage yield



Marginal inventory holding costs

=

Pure storage costs

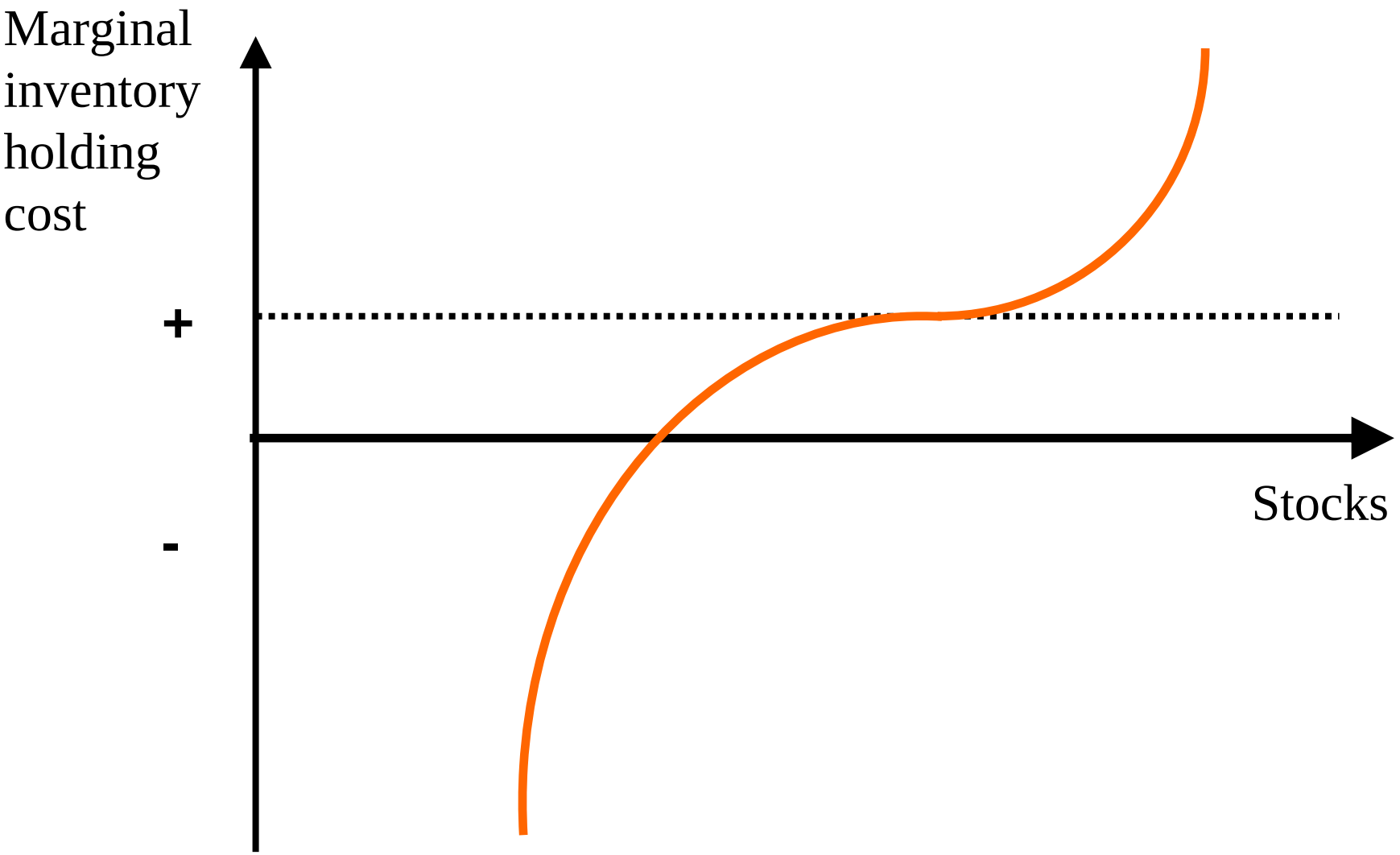
–

Stock-out yield

–

Coverage yield

Marginal inventory holding cost



2.3. Convenience yield, forward and futures contracts

- Futures and forward contracts give the possibility to obtain a physical delivery at expiration
- They insure the future availability of the merchandise
- There is a convenience yield associated to these contracts

$$C(t,T)$$

$$CY_{Contracts} < CY_{Inventories}$$

1. Quality, volume, localization
2. Only inventories give the possibility to benefit from an unexpected prices rise
3. There is no stockout yield associated with the holding of a contract

Section 3. Empirical tests on the theory of storage

3.1. Empirical implications of the theory

3.2. Empirical tests : a few results

3.1. Empirical implications of the theory

Direct implication

- Positive correlation between the basis and the inventory level

Indirect implication

- Basis is more volatile in backwardation
- In backwardation, spot prices are more volatile than futures prices
- Negative correlation between the convenience yield and the basis

For seasonal commodities, two more implications

1. The convenience yield must rise when the harvest comes near

2. Futures prices with an expiration date situated before or after the harvest have a different behavior

3.2. Empirical tests : a few results

- **Agricultural commodities** :

  The convenience yield is high just before the harvest and low just after the harvest

- **Seasonal and industrial commodities**

- There is seasonality in the behavior of the convenience yield (only for seasonal commodities)

- The behavior of the basis changes with the level of pure storage costs and with seasonality

- For industrial commodities, the basis is affected by changes in the economic cycles :

  During economic recovery, supply adapts itself lately to the demand, inventories are low,

  the basis is negative and volatile.

Empirical tests on the petroleum market

The petroleum market is characterized by:

1. Seasonality in the demand
2. Joint production process
3. Analysis of stock data:
   - Influence of strategic stocks?
   - Stocks of producing countries?
   - Stocks in oil fields, in pipelines, in tankers?

A few results on the petroleum market

- The convenience yield on the crude oil market has an evolution which is opposite to the evolution of the convenience yield on the products

- Results are less convincing on the crude oil market than on the products market

Conclusion on empirical tests

- The theory of storage is generally validated
- The basis behavior changes with the particularities of the commodity considered
- **Empirical examination of the relationship between prices and stocks, which is at the center of the theory, remains relatively scarce**

Section 4. Critiques of the theory

4.1. Convenience yield and the nature of stocks

4.2. Transformation costs

4.1. Convenience yield and the nature of stocks

- The convenience yield associated to strategic stocks is lower than the convenience yield associated to industrial stocks
- On the cocoa market, the evolution of the basis gives a faithful image of world stocks; this is not true for the coffee market
- The results of empirical tests change with the quality, the availability, and the localization of stocks

4.2. Transformation costs

1. Stock data frequently reassemble heterogeneous stocks. This explains why there are stocks in backwardation

   Example : 2 inventories located in A and B

   A : abundance

   B : stock-out

   (A + B) : stocks are hold in backwardation

2. If some stocks are hold in backwardation, it is because the study of their spatial and temporal allocation leads the operators to keep them

Transformation costs : implications

1. The theory of transformation costs shows that the convenience is often over-estimated

2. This analysis does not imply, however, that there is no convenience yield

3. It is very difficult to know where the aggregation phenomenon starts and where it stops

Section 5. Conclusion

Central question : how is it possible to explain that stocks are hold in backwardation ?

- Uncertainty on supply and demand
- Rigidity:
  - High fixed costs (transportation, storage, transformation, commercialization)
  - Distance production/consumption
  - Quality differentials

Relationship spot price / futures price

$$F(t,T) = S(t) + C_S(t,T) - C_y(t)$$

- F(t,T) : futures price at t, for delivery at T
- S(t) : spot price at date t,
- $C_S(t,T)$: marginal storage cost between t and T
- $C_y(t)$: marginal convenience yield at t

- 3 variables explaining the behavior of the futures price :
  - Spot price S
  - Convenience yield C_Y
  - Interest rate
- S & C_Y positively correlated
- Asymmetrical behavior of the basis

- Reconciliation of the storage and normal backwardation theories ?
- Recent evolution of the relationship between prices and stocks?
- Recent analysis of the convenience yield ?