II

The Prospects for ENSO Markets

4
Why Futures and Options?

In this chapter, I turn my focus from ENSO risk to the prospects for sustainable trading of that risk. Indexes of ENSO, and teleconnections more generally, could be traded using various financial instruments including over-the-counter (OTC) swaps, index-based (re)insurance, insurance-linked securities (ILS), or exchange-traded derivatives, such as futures and options.

Each of those candidates could provide roughly comparable risk protection to hedgers. However, some have qualities, like continuous trading or additional transparency in pricing, that match particularly well with teleconnections risk. In this chapter I introduce:

- some of the basic characteristics that I believe teleconnection markets should posses; and
- the hypothesis that the natural home for teleconnection risk (particularly ENSO risk) is on futures and options exchanges.

This chapter describes the market structures associated with a host of financial instruments and ultimately makes a value judgment about which structure will support better social outcomes. In that sense, it resembles ongoing discussions of US financial regulations. As regulators implement the Dodd-Frank reforms, they are looking to existing research to answer questions like, "Do some types of financial contracts encourage unsafe borrowing?" and "Do some market structures promote greater access to transactions at the best available prices?".

So, if you are familiar with these candidate financial instruments and how they might match with the risks I discuss in chapters 2 and 10, then you should feel free to skip this chapter. However, keep in mind that the original research in chapters 5 and 7 is a response to the arguments I make here. After I've developed a case for futures and options here, I try to knock that case down in the following chapters by asking "What is the probability that any futures or options market will succeed?" and "Do market professionals agree that El Niño/La Niña indexes can succeed as exchange-traded derivatives?".

Desirable market qualities

Our recent financial crisis centered on insurance against housing prices. Clearly, that insurance undermined social outcomes. But it doesn't follow logically that we should all stop buying home insurance.

So what distinguishes a financial contract with questionable (or negative) social value from our home insurance or the corn futures that a farmer uses to protect his livelihood from falling prices? What basic market characteristics will allow ENSO and other teleconnection index products to improve the way we make decisions about climate risk?

It is important to have these goals laid out explicitly because new markets rarely form spontaneously. Much more often they are the result of years of hard work by motivated people like the founder of the Chicago Climate Exchange (CCX), Richard Sandor. Despite his strong belief that markets can promote efficient social outcomes, he insists they are man-made creations[1]:

> I was recently invited to lecture students at a leading American business school. Most of these MBA candidates were surprised to find out that financial futures were not introduced until the 1970s. They believed, as most people did, that these innovations have always existed. This simple example highlights the common misconception that efficient markets materialized spontaneously... [T]he evolution of markets is a multi-year, multi-stage process...

[1] Richard Sandor. *Good Derivatives: A Story of Financial and Environmental Innovation*. John Wiley and Sons, 2012

Market pioneers have agency in shaping their creations. So, its important that they have a sense of the market characteristics that foster social value.

In this chapter, I focus on a handful of market ideals that I think ENSO and other teleconnection-indexed financial contracts should promote. Those include:

- **Public pricing information** - A market for teleconnection risk should generate prices that provide the public with implicit forecasts of disasters. To the extent that a teleconnection risk is influenced by global climate change, its markets should provide us with dollar-backed[2] forecasts of that phenomenon as well. While all of the candidate market types would generate this information, only some would share it publicly as a matter of course.
- **Dynamic pricing** - Some market types allow hedgers and speculators to enter into trades at any time. In dynamically priced markets, prices change to reflect new information as it becomes available. By contrast, classic insurance markets use static pricing. All trades occur before any special information is available, The price of the trade is based purely off long-term historical data. Neoclassically rational hedgers should not care whether the insurance

[2] ... if indirect...

they are buying is priced statically or dynamically. In reality, this distinction may matter a great deal as hedgers are particularly motivated to enter a trade when they believe a payout is likely - even if the price of the risk protection has adjusted to fully reflect the change in that likelihood.

- **Two-sided pricing** - In some markets, prices are set by one side of the trade (buyers or sellers) and a transaction is only consummated when the other side meets that target price. For example, it is difficult to haggle with Amazon.com about the price of a new kindle book. You either decide the book is worth the price asked or you walk away. In a two-sided market, competing buyers or sellers change the prices at which they would transact and a trade occurs when those *shouts* cross.
- **Modest leverage** - Some degree of leverage (the use of borrowed money to enter into risk transfer agreements) offers risk sellers the opportunity to meet internal profit targets without charging hedgers high risk premiums. Furthermore, it can lower the barriers to entry for new risk sellers, increasing competition. However, leverage may amplify the risk of trade. A market can balance the need for competition (supported by leverage) and the need for stability (compromised by leverage) by enforcing predictable margining rules.
- **Flexible hedges** - Hedgers prefer risk management packages that closely match their specific risk exposures. However, the more specifically a risk package is tailored to the profile of a particular hedger, the less likely it is to appeal to a diverse pool of hedgers. This means that there is often a trade-off between liquidity and basis risk. Some market types attempt to minimize the basis risk of hedgers by allowing customized transactions. Others emphasize liquidity, offering only the most standardized contracts. Ideally, teleconnection markets will strike a balance between those two goals.

In the following sections, I look at each of these characteristics and discuss how different financial instruments promote or undermine them.

Public pricing information

Forecast fatigue

Why is it so important that ENSO markets provide forecast information? Won't that information be redundant since, as I showed in chapter 3, NMS already provide forecasts of teleconnections anomalies

each month?

In the case of ENSO, the information from markets will be valuable precisely because there is so much publicly available forecasting. Hedgers find it difficult to process competing forecasts in the absence of definitive baseline reference points, like the prices from markets. In any given month, some NMS predict looming catastrophe while others tell hedgers not to worry. Figure 4.1 provides a sense of the range of forecasts throughout 2012, a year in which conditions were ultimately normal. In early 2012 some models predicted historically strong El Niño while others suggested a light La Niña.

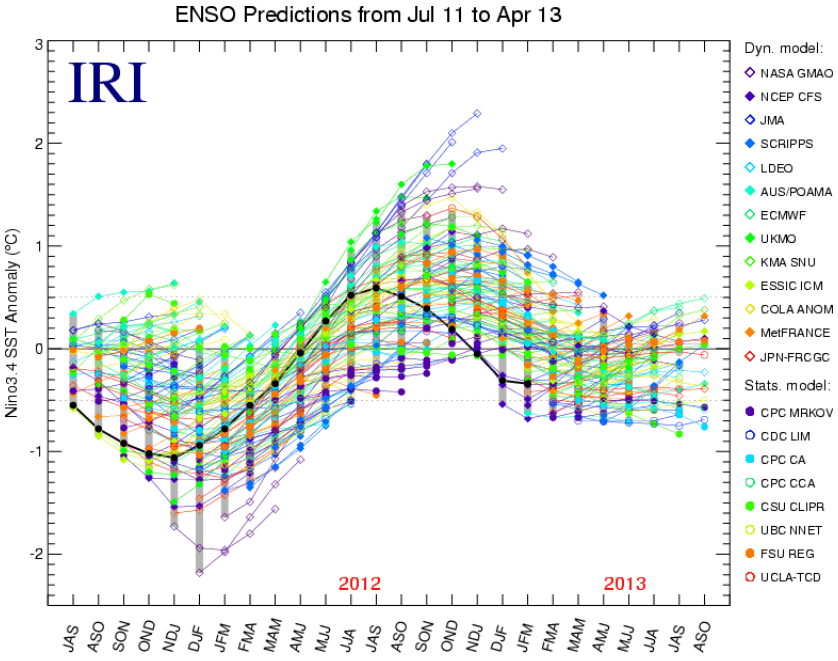

Figure 4.1: Forecasts of ENSO index anomalies between July 2011 and April 2013 compiled by Columbia University's International Research Institute for Climate and Society http://portal.iri.columbia.edu/

The climatologists putting together forecasts are comfortable seeing that range of opinions. Indeed, some researchers harness that disagreement among modelers to provide probabilistic forecasts [3] [4]. But for an individual Peruvian or Australian, making serious financial decisions based on ENSO forecasts, that disagreement is just confusing.

Not only are forecasts confusing, but they often make it to hedgers only after they've been filtered by media that is understandably more interested in the headline "El Niño in 2012 according to respected climate group" than its probabilistic cousin, "Climate scientists disagree about 2012 El Niño." Seen through that filter, forecasts would trace the outer edge of the band in figure 4.1, often switching rapidly between La Niña and El Niño.

In the course of my work with hedgers in Peru, forecast fatigue came up often. Extreme forecasts followed by underwhelming events

[3] CAS Coelho, S Pezzulli, M Balmaseda, FJ Doblas-Reyes, and DB StephENSOn. Forecast calibration and combination: A simple Bayesian approach for ENSO. *Journal of Climate*, 17(7):1504–1516, 2004

[4] Lifeng Luo, Eric F Wood, and Ming Pan. Bayesian merging of multiple climate model forecasts for seasonal hydrological predictions. *Journal of Geophysical Research: Atmospheres*, 112(D10), 2007

have undermined the trust of Peruvians and left many with mistaken impressions about which years truly saw catastrophic ENSO anomalies. One surprising example came from a large fishing company[5]. A manager told us that his firm would easily withstand an extreme El Niño, as higher prices would offset lower catches. Over the course of the meeting, it gradually became clear that his optimism came from recent experience of moderate events that had been forecast as extreme earlier in the season.[6]

[5] The example is surprising because large fishing companies are, in my experience, particularly adept at valuing probabilistic forecasts.

[6] His belief was not shared by any of the other fisheries we spoke with and certainly at odds with the industry-wide bankruptcy and nationalization that followed the 1982/1983 El Niño.

Unfortunately, the manager's confusion is common in circumstances where individuals are sorting though forecasts as they make risk management decisions. Reading about the response of New Orleans residents to hurricane forecasts in Silver [2012], I found a passage that could as well have described that manager:

> Most New Orleanians had not been alive when the last catastrophic storm, Hurricane Betsy, had hit the city in 1965. And those who had been, by definition, had survived it. "If I survived Hurricane Betsy, I can survive that one, too. We all ride the hurricanes, you know," an elderly resident who stayed in the city later told public officials.[7] Responses like these were typical. Studies from Katrina and other storms have found that having survived a hurricane makes one less likely to evacuate the next time one comes.[8]

[7] Keith Elder, Sudha Xirasagar, Nancy Miller, Shelly Ann Bowen, Saundra Glover, and Crystal Piper. African Americans' decisions not to evacuate New Orleans before Hurricane Katrina: a qualitative study. *American Journal of Public Health*, 97(Supplement_1):S124–S129, 2007

[8] Hugh Gladwin and Walter G Peacock. Warning and evacuation: A night for hard houses. *Hurricane Andrew: Gender, ethnicity and the sociology of disasters*, pages 52–74, 1997

Exchange-traded markets as a touchstone for forecasts

Corn farmers face the same problem as El Niño hedgers. There are many forecasts of future prices competing for their attention. Fortunately, they have the option of allowing markets to filter those forecasts.

Some, but not all, markets could provide that pricing information to the public and become the default reference point for ENSO hedgers across the world. An options market would be particularly valuable in this regard. Options prices would provide not just a consensus forecast of the absolute index value, but an intuitive measure of the uncertainty around that forecast. Ideally those option prices would become the default reference for media covering ENSO, just as they have for agricultural commodities.

Exchange-traded markets do an excellent job of providing public pricing information. Exchanges generally use order-book systems, where the lowest outstanding bid (offer to buy at a specified price) and highest ask (offers to sell at a specified price) are displayed to the public. That is meant to ensure that traders always know the price at which they could transact on either side of the market immediately. Market makers are required to always post spreads (pairs of bids and offers) that are good up to a pre-specified order size. By law and convention, exchanges post not only bids and asks, but all consummated

transaction prices to central repositories. The information from these repositories is often available to members of the general public for little or no cost. In recent years, those prices have been circulated for free by online brokerages and services like Google Finance.

Block trading and pricing information

There is an increasingly important exception to the general rule that exchange-traded markets provide the highest quality public pricing information: block trades. These are bilaterally negotiated trades (with terms often set over the phone) that are reported to an exchange after they have been consummated. A block trade's underlying asset is already traded on the exchange and its counter-party risk is managed like a normal futures or options position.

Traditionally, block trades were favored by large institutional investors worried that their bulk buying or selling would move market prices against them. Through block trades those large investors find counter-parties that provide them a less favorable price than is available on the market. In exchange for accepting that less favorable price, they receive certainty about the average price they will receive for their full transaction.[9]

[9] Mallaby [2011] provides an excellent introduction to block trading in it's chapter on hedge fund mogul Paul Tudor Jones.

Block trades provide the public with the same price and size information as order-book trades, but only after the trade has been consummated. Block trading provides less information about the prices of trades that could be consummated at any given moment. For exactly this reason, the CFTC is attempting to craft its Dodd-Frank rules to discourage market participants that benefit from informational asymmetries in OTC markets from herding their transactions over to block trading on exchanges[10] [11].

[10] Commodity Futures Trading Commission Office of Public Affairs. Final rulemaking on procedures to establish appropriate minimum block sizes for large notional off-facility swaps and block trades; further measures to protect the identities of parties to swap transactions, May 16 2013. URL http://www.cftc.gov/ucm/groups/public/@newsroom/documents/file/block_factsheet_final.pdf

[11] Joe Rennison. Futurisation debate shifts to block trading rules, March 27 2013b

My interviews of exchanges and hedge funds suggested that block trading currently dominates on-exchange weather and catastrophe transactions. Some key market participants suggested that block trading may also dominate ENSO and teleconnection trading, should those risks list on an exchange. Given that, it is important to recognize that exchange-trading may not offer the clear improvements in price transparency implied by an offer-book.

Bilaterally-traded markets

In uncleared OTC swaps and ILS, a potential hedger needs to contact a recognized broker (generally by phone) simply to get indicative pricing. As Michael Lewis' *The Big Short* details, in extreme circumstances, those indicative prices may bear little resemblance to actual transaction values[12]:

[12] Michael Lewis. *The Big Short: Inside the Doomsday Machine*. WW Norton, 2010

With no one else buying and selling exactly what [hedge fund man-

> ager,] Michael Burry[,] was buying and selling, there was no hard evidence what these things were worth - so they were worth whatever Goldman Sachs and Morgan Stanley said they were worth... [Burry began] asking Wall Street traders if they would be willing to sell him even more credit default swaps at the price they claimed they were worth, knowing that they were not. "Never once has any counterparty been willing to sell me my list at my marks," he wrote in an e-mail. "Eighty to ninety per cent of the names on my list are not even available at any price." A properly functioning market would assimilate new information into the prices of securities; this multi-trillion-dollar market in sub-prime mortgage risk never budged.

Even in the most liquid OTC markets, indicative pricing may be difficult to find. Duffie [2012] summarizes recent research on price dispersion within bilateral markets, much of which has been influential in Dodd-Frank rule-making:

> In a relatively opaque OTC market, different investors may pay quite different prices for the same asset at essentially the same time. The investors may vary in terms of their relative bargaining power, their access to alternative trading opportunities, the quality of their information both about the fundamentals of the asset and about recent transactions. For example, Green et al. [2007] document dramatic variation across investors in the prices paid for the same municipal bond. Massa and Simonov [2003] report dispersion in the prices at which different dealers trade the same Italian government bonds. Ashcraft and Duffie [2007]... [shows]... that the rate at which a pair of banks negotiate a loan of federal funds in the overnight inter-bank market at a given time of day, relative to the average rate negotiated by other pairs of banks at the same time of day, varies according to the relative cash holdings of the two banks at that moment of the day, the degree to which the two banks are active in the inter-bank lending market, and the extent to which the banks have had a prior borrower-lender relationship, among other factors.

So, bilateral markets struggle to provide even institutional investors with the pricing information that is almost definitional in traditional exchange-traded markets. But that problem is compounded by the fact that only institutional financial firms[13] can transact in specialized bilateral markets, such as OTC swaps and ILS. The distinction between retail and institutional investors is drawn both by explicit regulation and through informal segregation[14].

Normal investors, even small hedge funds, do not have working relationships with the brokers that provide indicative prices on specialized OTC markets. Again, Lewis provides an excellent example of this problem, as one of the investment funds he follows, Cornwall Capital, is repeatedly turned away as they try to establish the brokerage relationship they need to bet against the sub-prime mortgage market[15]. Just as the mortgage market is beginning to collapse, days

[13] Such firms are called "eligible contract participants" by US regulators.

[14] Davis Polk. Client memorandum: CFTC and SEC adopt final swap dealer, major swap participant and eligible contract participant definitions. Technical report, Davis Polk & Wardwell LLP, May 2012. URL http://www.davispolk.com/files/Publication/f5da8563-1257-4be7-b1a1-7d179b7fecbd/Presentation/PublicationAttachment/6eb3305b-a70e-477a-b3e3-a12a6e69e0a9/050212_Swap_Entity_Definitions.pdf

[15] Michael Lewis. *The Big Short: Inside the Doomsday Machine*. WW Norton, 2010

after convincing an investment bank to grant them special permission to trade, Cornwall Capital sees the first prices from actively-traded securities linked to the mortgage market. That pricing information, more reliable than what was available over the telephone from brokers, immediately provided powerful forecast information:

> Five days later, on February 21, [2007,] the market began to trade an index of CDOs called the TABX. For the first time, Charlie Ledley, [one of Cornwall Capital's founders,] and everyone else in the market, was able to see on a screen the price of one of these CDOs. The price confirmed Cornwall's thesis in a way that no amount of conversation with market insiders ever could have. After the first day of trading, the tranche that took losses when the underlying bonds experienced losses of more than 15 percent of the pool - the double-A-rated tranche that Cornwall had bet against - closed at 49.25: It had lost more than half its value.

The Dodd-Frank financial reforms are intent on reshaping information flows in OTC swaps markets to improve public pricing information. One pillar of Dodd-Frank's derivative-focused Title VII mandates reporting of basic trade information on many bilateral markets to *Swaps Data Repositories*. This change is meant to improve *post-trade* transparency (i.e. transparency on trades that have happened) ensuring that many bilateral markets provide pricing information comparable to exchange-traded markets. However, the Dodd-Frank rules related to *pre-trade transparency* (i.e. transparency on transaction prices and sizes that are currently available, similar to bid/ask spreads in exchange-traded markets) remain in flux.

It seems likely that swaps markets will maintain some of the trading practices that stifle the flow of information. Transactions on many bilateral markets will remain phone-based, even if those phone-based transaction systems are forced to run parallel to electronic transaction systems with order-book-like features. The dealers that benefit from the informational asymmetries highlighted in Duffie [2012] recently won a major regulatory battle regarding pre-trade transparency. They successfully defeated a CFTC rule that would have mandated that traders solicit prices from at least five firms before a trade can be executed. Instead, the threshold will be two firms, eventually increasing to three in the future[16].

[16] Jamila Trindle. Regulators strike compromise on new derivatives rules, May 16 2013

Reinsurance

Reinsurance markets[17] offer the lowest level of post-trade transparency of any of the market types discussed here. There is no central repository collecting recent transaction data and no regulatory mandate to create one. Even if there were such a mandate, policies tend to be highly customized, making price comparison difficult. Post-trade

[17] Note that although ILS involve insurance-like risk, they trade on secondary markets with bilateral-negotiation.

transparency is almost entirely at the discretion of brokers. Those brokers tend to provide indicative price ranges rather than recent transaction prices.

Pre-trade transparency is also lower in reinsurance markets than in even the least transparent OTC swaps markets. Reinsurance is a one-sided market - sellers generally do not buy and buyers generally do not sell. Whereas brokers in OTC markets quote both a price at which they would buy and sell, reinsurers only quote a price at which they would sell coverage. As I'll discuss in chapter 7, many traditional reinsurers are strictly opposed to using their balance sheets in any way except to sell insurance.

Summary of public pricing information

Pre-trade transparency will be critical to establishing trust in a market with an underlying index that may initially appear complicated to first time hedgers without climate expertise. The climate science behind teleconnections is relatively new and many firms facing climate risk related to teleconnections will have limited prior exposure to formal financial risk management.

In theory, teleconnections markets should be safe for such uninformed traders because they would be homogeneous, cash-settled contracts, based on simple indexes, published by trusted third parties. Historical data on their underlying index is freely available. Hence, even relatively uninformed traders will have all the information they need to make prudent risk management decisions using this market, even if they lack advanced climate modeling capabilities.

In practice, hedgers' comfort will be a function of the market structure. For the market to gain the trust of the full complement of firms with climate risk, those hedgers must believe that they are not systematically facing larger spreads than better connected traders. Exchange markets provide that assurance by promoting high levels of price transparency.

For that reason, I believe exchange-traded derivatives are slightly better suited to providing public information about the ENSO cycle than bilaterally-traded or reinsurance markets. In their most basic form, exchange-traded markets price the gold standard for transparency in pricing. Block trading is on the rise and it blurs the line between bilateral markets and exchange-traded markets. But even with substantial block trading, futures and options prices have anchored forecasts of many risky events for decades.

Dynamic pricing

In chapter 3 I discussed the tension between prediction and insurance. Prediction opens up the possibility of asymmetric information. Insurers are concerned about the adverse selection created by that asymmetric information. Hence, insurers limit the coverage that they sell on phenomena subject to prediction that is more accurate than long-term averages. That is a problem for a phenomenon like ENSO, for which forecasts improve throughout the year. Instead of using static prices based on long-term averages and a hard sales closing date, the price for ENSO coverage should change dynamically with forecasts.

Sales closing

The reinsurance company selling GlobalAgRisk's El Niño coverage set the sales closing date for their coverage ahead of ENSO's predictive window. That meant that hedgers had to finalize their purchase decision roughly one year before the period of coverage.

Sales closing dates are problematic for two reasons. First, there is no guarantee that the insurance company sets the sales closing date correctly. Forecasts of oscillations are steadily improving and there is no certainty that the insurance company will continually set the correct cut-off date for their insurance sales. Second, sales closing dates increase the opportunity cost of buying protection and disregard the psychological tendencies of hedgers to delay their decisions.

In 2010 GlobalAgRisk's reinsurance partner had set their sales closing date in March. That year, they were in late stage negotiations to sell coverage to a fishing conglomerate as the date approached. Interested in consummating a first sale, they agreed to give the firm two extra weeks to make a decision. It is impossible to know exactly why they decided against purchasing coverage that year. However, we do know now that around that time, the conglomerate received analysis from their own in-house climate experts suggesting that a La Niña was increasingly likely in the upcoming year.

That chain of events was enough to convince the reinsurer that they ought to push back the closing date to January for the following sales season.

As climate scientists improve their forecasts of ENSO, that date will continue to move further and further back. One response to improving forecasts is to encourage multi-year contracts. Those are very uncommon in traditional reinsurance markets, where firms are always hoping to take advantage of the price spikes that follow large loss events[18]. Unfortunately, multi-year contracts avoid the arms race between buyers and sellers prediction only by pushing the effective sales closing date out years before the period of coverage.

[18] Note that most ILS have a three year term.

Having to pay an insurance premium a full year in advance of the period of insurance coverage implies an opportunity cost for any hedger whose business returns exceed the discount factor that their insurer uses for the time value of their premiums. That discount factor will generally be low.

This problem concerned me greatly as I worked on GlobalAgRisk's El Niño insurance. In an unpublished manuscript, I explored the opportunity cost of El Niño insurance for farm households in depth. My simulations suggested that the profits earned by reinvesting premiums in the years before the disaster, either in safe investments or in the households' own activities, often provided risk protection equal to or better than that offered by insurance coverage priced at the market rate. The difference is stark when compounded over many years. So, in some cases, farm households face steep opportunity costs that overwhelm the value of El Niño risk protection[19]. Multi-year contracts will not remedy that problem.

[19] Grant Cavanaugh. Opportunity cost and the value of microinsurance: a simulation of farmers in northern Peru facing El Niño risk. Working paper, December 2011

In addition to this rational economic consideration, there are important psychological tendencies that discourage firms from paying premiums well in advance of their periods of coverage. Skees and Cavanaugh [2013] discusses these tendencies in the context of insurance against catastrophic risks in the developing world. They are important enough factors to make or break innovative new insurance projects.

Derivatives and dynamic pricing

I believe it absolutely vital that teleconnection markets their prices as new forecast information becomes available. Without that dynamic pricing, teleconnection markets will handicap their ability to attract new hedgers, insisting on sales closing dates and long-term contracts that simply are not attractive to many potential hedgers.

Derivatives (including OTC derivatives) have a distinct advantage over reinsurance and primary ILS markets in the way that they provide for dynamic pricing. To be sure, adverse selection can create *lemon problems*[20] that undermine liquidity in derivatives markets, just as in insurance markets[21,22,23,24]. However, derivatives are clearly capable of pricing teleconnection forecasts in the manner presented in chapter 3.

[20] George A Akerlof. The market for "lemons": Quality uncertainty and the market mechanism. *The quarterly journal of economics*, pages 488–500, 1970

[21] Thomas E Copeland and Dan Galai. Information effects on the bid-ask spread. *Journal of Finance*, 38(5):1457–1469, 1983

[22] Lawrence R Glosten and Paul R Milgrom. Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics*, 14 (1):71–100, 1985

[23] Albert S Kyle. Continuous auctions and insider trading. *Econometrica: Journal of the Econometric Society*, pages 1315–1335, 1985

[24] Hayne E Leland. Insider trading: Should it be prohibited? *Journal of Political Economy*, pages 859–887, 1992

While it is theoretically possible for insurance companies to offer such dynamic pricing, that is not standard practice. Similarly, in ILS markets, risk tends to be priced at the time of the security issuance. There is some dynamic pricing on secondary markets. But the interviews in chapter 7 suggest that prominent ILS traders consider *Live CAT* trading (i.e. trading on the secondary market when forecasts are available) beyond their core competency.

Two-sided pricing

Teleconnections create winners and losers. Where Peruvians see El Niño anomalies as harbingers of disaster, American insurers see them as an indicator of strong underwriting profits thanks to a decreased likelihood of major Atlantic hurricanes. In chapters 2 and 10, I estimate the size of some of these major offsetting hedging groups for ENSO and the Arctic Oscillation respectively.

The fact that ENSO's impacts are so diverse across time and space suggests that that an ideal teleconnections market would allow hedgers with offsetting risk profiles to trade directly with one another. Similarly, firms with the expertise to forecast ENSO should have the opportunity to enter that market as buyers or sellers, depending on the prevailing price and spread.

Markets where buyers and sellers simultaneously negotiate, including those in most derivatives, are called two-sided. Brokers or market makers offer their clients spreads, pairs of prices at which they could buy or sell.

By contrast, in one-sided markets such as reinsurance and ILS, there is a clear distinction between buyers and sellers. One party (generally the seller in reinsurance) sets the price and the individuals on the other side of the trade (generally the buyers in reinsurance) have the option to take or leave that offer[25]. In reinsurance markets in particular, the divide between buyer and seller is enshrined in regulations and laws that specify the capital reserving requirements for insurance companies and bar non-insurance companies from selling insurance coverage. Indeed, the difficulty of starting new (re)insurance companies is at the heart of the reinsurance pricing cycle[26].

Theoretically, a one-sided market is perfectly appropriate for some types of risks. For example, there is no large group of firms that naturally benefits from an earthquake[27]. So, the market for risk protection is unlikely to be *balanced*, with hedgers happy to take risk on both sides of an earthquake trade. Instead, one side of the market (the side that is short earthquakes - losing money if they do occur) will be provided by reinsurers. Those reinsurers expect to be compensated for taking that risk.

If teleconnections risk were offered only as reinsurance, firms with offsetting risks would only transact through a reinsurance firm, unless one of the offsetting firms was willing to become an insurer themselves. Breaking what could be a single transaction into two suggests additional transaction costs (e.g. now there are two agreements that must be reviewed by lawyers) and it also introduces a speculator, who will collect fees from both sides of the trade. If instead the trade were direct, it might simply transfer risk at a close-to-actuarially-fair price

[25] Such markets certainly have some informal negotiation or *work-up*, where buyers and sellers negotiate up the size of a transaction at an agreed upon price. But the distinction between buyer and seller remains clear.

[26] K. Froot. *The Financing of Catastrophe Risk*. University of Chicago Press, 1999

[27] . . . ignoring the select few firms directly involved in the clean-up and rebuilding after an earthquake.

and still benefit both sides.

Modest leverage

In a frictionless world, all of the most common methods of managing counter-party risk in a trade should be equivalent[28]. In reality, those different methods can promote radically different levels of counter-party risk for individual clients, different barriers to entry for new sources of risk capital, and even different prices of risk for hedgers.

[28] A.S. Mello and J.E. Reilly. Margins, liquidity and the cost of hedging. Technical report, MIT's Center for Energy and Environmental Policy Research, 2012

At one extreme sit collateralized reinsurance and ILS. In those markets, the full amount needed to pay worst case scenario claims is set aside using a Special Purpose Vehicle (SPV), essentially an insurance company created simply to hold the capital for that ILS deal. That money is supposed to be invested in safe, liquid assets, so that clients are assured that their funds will be available at a moment's notice after an event. In fact, those agreements are not entirely without credit risk because SPVs have managed their collateral through swap agreement with third parties[29]. Even with that introduction of counter-party risk (through the swap agreements), ILS and similar reinsurance type arrangements offer protection with relatively little counter-party risk compared to other candidate instruments that could be the basis of teleconnection markets.

[29] A. Kurtov, editor. *Investing in Insurance Risk: Insurance-Linked Securities - A Practitioner's Perspective*. Risk Books, June 2010

On the other end of the spectrum, many OTC derivatives contracts are intended to require no collateral posting. Cash does not change hands until those contracts are settled. That is a source of worry for regulators and under Dodd-Frank, many OTC contracts may be subjected to more stringent counter-party risk measures than exchange-traded derivatives[30] [31].

[30] Darrell Duffie. Futurization of swaps, January 28 2013. URL http://www.darrellduffie.com/uploads/policy/DuffieBGOV_FuturizationOfSwaps.pdf

[31] Robert Litan. Futurization of swaps, January 14 2013. URL http://www.darrellduffie.com/uploads/policy/BGOV_FuturizationOfSwaps.pdf

In between those extremes are normal reinsurance, which requires substantial capital reserving, and exchange-traded derivatives, which uses clear margining rules to adjust the amount of collateral required by each side of a trade as prices change. See Mello and Reilly [2012] for a simple example contrasting margining on exchanges according to standard margin rules with OTC swaps.

To be sure, credit risk is not desirable for the long-term stability of a market. However, the ILS and reinsurance markets' response to counter-party risk is costly in the short-term and tends to increase the barriers to entry for new capacity providers. Only firms with substantial capital can cover the risk of a full loss upfront. Those firms will then calculate their returns as a percentage of the full capital allocation.

For ENSO, I personally favor modest leverage managed through clear margining rules, as on an exchange. To understand the advantages of modest leverage, I've prepared a simple economic model that I

believe bears a strong resemblance to current market dynamics.

Assume the following terms:

- Equity - E
- Return on equity (performance) target - T
- Profit target - TE
- Leverage ratio - L
- Assets under management - LE
- Gross interest rate - I
- Expected return as percentage of assets under management - R

To meet their profit target, traders must follow equation 4.1, across their portfolios.

$$RLE - (L-1)EI \geq TE \tag{4.1}$$

If $L = 1$ then the trading firm is not leveraged, and they must go after a portfolio of opportunities where collectively $R \geq T$. In times when there are plenty of lucrative deals available, investors raise their performance target T, making sure that there is never a persistent opportunity to take deals where $R >> T$. This is the case for much of the reinsurance industry. Low levels of liquidity mean that firms simply will not look at offers with low markups over the underlying risk.

When the market has perfect pricing (i.e. pricing that exactly matched the underlying risk), $R = 1$. So, a social planner looking simply to minimize price while keeping the market functioning would set $R = 1 + \epsilon$ where ϵ is a very small value.

As $\epsilon \to 0$, then it is necessary for $L \to +\infty$ to satisfy equation 4.1. Hence, there is a trade off between the short-term goals of the firms providing hedges and the customers buying them that can theoretically be solved using leverage.

Of course, there is a potential downside to leverage. If we imagine R is stochastic, then a single stochastic instance of a low R with infinite leverage cause immense disappointment ($RLE - (L-1)EI \to -\infty$) and equation 4.1 cannot be satisfied.

So there is a balance to be struck between leverage and competitive prices. ILS and reinsurance lie on one extreme of that balance. With little leverage each individual trade must offer returns at or near a firm's profit target. In the 2008 crisis, OTC derivatives markets were revealed to have experimented with the other extreme. Exchange-traded derivatives with meaningful collateral regulations stand in the middle and represent the best short term option for teleconnection markets.

Flexible hedges

The link between the frequency and severity of natural disasters is generally non-linear. Instead, they tend to follow power law distributions (see Gutenberg and Richter [1965] for earthquakes, Malamud et al. [1998] for forest fires, and Malamud et al. [1996] and Turcotte and Greene [1993] for floods) that mean that the next El Niño that is bigger than 1997/1998 may cause flooding in northern Peru an order of magnitude larger than anything ever seen before. (As I showed in chapter 3, the same is not necessarily true for the underlying SST index.)

If indeed ENSO and other teleconnections create power-law distributed risks then simple linear payouts will do a poor job representing the underlying risk profiles of hedgers (which is non-linear). Duffie and Jackson [1989], suggests that hedging interest will concentrate in markets that reflect the risk aversion weighted losses in the portfolios of hedging firms. So, linear payouts are not only problematic insofar as they create basis risk for hedgers, but that basis risk may undermine liquidity, further depressing the value of the hedge.

Among the candidates discussed here, the only risk market type entirely wed to linear payouts is futures. As Sandor [2012] recounts, the CBOT had to discover this limitation on their catastrophe loss futures through trial and error:

> The CBOT catastrophe insurance futures didn't mimic reinsurance. Option call spreads better simulated the reinsurance layers that the insurance industry was accustomed to. Consequently, the exchange redesigned the contracts and began trading options contracts on September 29, 1995, using the Property Claims Services' (PCS) loss estimates. . . .Later on, due to the lack of industry demand, PCS-indexed insurance futures were dropped entirely. Only cash options on PCS industry estimates were offered for trading.

In options markets hedgers are free to combine contrasts with linear payouts above or below specified index values to produce more flexible risk protection. Indeed, the basic payout function used for GlobalAgRisk's El Niño insurance (see chapter 2) is entirely reproducible using options. However, Sandor [2012] suggests that the CBOT's options remained at a disadvantage relative to reinsurance and ILS insofar as they lacked flexibility both for buyers and sellers:

> Cat bonds were considered more attractive than PCS options because of their inherent flexibility. In a cat bond, a reinsurance company can customize its hedge to be indexed on its own losses, as is done in traditional reinsurance, or it can be indexed on PCS. Moreover, they can be structured to resemble a traditional excess-of-loss reinsurance contract or a quota-share contract, whereby investors share proportionately in the gains and losses of the reinsurer. Cat bonds and the

> SPV structure also provide the issuing insurance company with access to a broader set of investors than PCS options. Some investors, such as pension funds and mutual funds, are restricted from transacting in derivatives such as PCS options, but are allowed to invest in securities, such as bonds or notes. The ability to offer principal-protected tranches of a note increases the investor base even further because there are some investors who can invest only in AAA-rated securities. This larger set of potential investors may be especially important for companies seeking to transfer large amounts of risk to the capital markets.

Sandor [2012] does not mention competitive pressures from OTC derivatives. Setting aside regulatory constraints on buyers and sellers, those contracts would offer the same design flexibility as reinsurance and ILS.

So, reinsurance, ILS, and OTC derivatives would likely offer hedgers of El Niño/La Niña and other teleconnection risks the most flexible protection. Options contracts are a suitable alternative given the relative simplicity of teleconnection indexes. Apart from a small group of specialized firms, futures will be the least attractive financial instrument for hedgers.

Summary of candidate financial instruments

I believe that a futures market with an overlaying options market, settled based on a futures price, offers the best available combination of public information, dynamic pricing two-sided pricing, and flexible hedges.

The Case-Shiller housing index market, has adopted this configuration, with most of its hedging activity occurring in options markets settled based on the underlying futures price. This market provides an excellent precedent for teleconnections risk management. It is based on a trusted index of a risk that, while fundamental to economic activity, was unmanaged until recently. Both markets look to attract hedgers previously unfamiliar with derivatives trading and do/could provide socially-valuable information in the form of prices.

It is worth noting that the distinction between OTC swaps and exchanges-traded derivative markets is blurring as a result of financial regulatory changes in the wake of the 2008/2009 financial crisis. In particular Title VII of the Dodd-Frank Act, requires OTC swaps trading to take place on an exchange. While the rules governing that transition are still being written and regulatory arbitrage may insulate many OTC swaps markets from this intended transition, it is worth noting that OTC swaps markets will increasingly display some of the characteristics noted here as particular to futures and options markets.

Also, ILS markets show enough secondary trading to provide some

public information about dynamic, two-sided pricing. However, as I discuss in chapter 6 trading remains thin and inaccessible to most investors.

So, while there are many viable alternatives, I do believe that the natural home for ENSO risk in particular is on exchange-traded futures and options markets. In the following chapters I test that hypothesis by looking at the probability of success for new contracts on those markets and by talking to catastrophic risk professionals.