Downloaded by [redacted] on [redacted]

MARCO AVELLANEDA

"That Crazy Boy From Búzios!"

Marco Avellaneda discusses his life and career with Dan Tudball

Brazil, 1975 or thereabouts: we are in Búzios, a small resort town a few hours out from Rio de Janeiro. Up until ten years prior, the town wasn't much more than a fishing village, but following a Yuletide visit by a certain Gallic sexpot, the town had subsequently become a magnet for the jet set, back when that term actually had some cachet. Luxurious villas, which had proliferated as quickly as the Brazilian Miracle of 1969–1973, had put the country on the global economic map. Around this time, out on Geribá or any one of the various *plaia* that define the tiny peninsula, it was commonplace to encounter a companionable young surfer by the name of Marco, the son of a retired Argentinean diplomat who had settled in town.

Although Marco wouldn't describe the passage of parties and surfing that constituted his day-to-day routine as a 'dark period' until much later on in his life, he was by now aware that there was something beyond catching waves and hanging out with Mick Jagger. Deciding exactly what lay past the uncertain volatility of the rock 'n' roll lifestyle was still as capricious as what name the Brazilian currency would go by tomorrow, but nevertheless there was an awareness of an awareness. Friends and acquaintances who streamed through the family home presented enticing glimpses of possible futures – artists and musicians like Caetano Veloso, Gilberto Gil, or Antonio Carlos Jobim censuring the politics of the day and its attendant boom-and-bust economy; stockbrokers sailing in on the profits of the recently invigorated (and soon to be emasculated) stock exchange.

Marco was aware that mathematics had something to do with it. His parents' final tour had taken the family to Paris from 1969 to 1973. There, Marco had been imbued with the sense that intellectual pursuits led to great things. Unavoidably, math had figured in this developmental period, first as an inevitable *sine qua non* of the French educational edifice, later as something for which the younger Marco began demonstrating more than just an emerging proclivity. The math took him to a lycée in Rio, where he attempted to teach the subject, but, beyond the money, the experience hadn't been particularly inspiring. Watching contemporaries leave for colleges and universities also stirred the desire to attain something academically, albeit without a definite goal.

Somehow, on occasion, he found himself making the two-hour bus trip to the Instituto Nacional de Matemática Pura e Aplicada (IMPA). A girl had mentioned something about someone enrolled there; IMPA was, and still is, the best school for mathematics in South America. The staff there couldn't help but be bemused, confronted with a local hero from Armação dos Búzios; no, he did not have a college degree. He had traveled over 100 miles. He would like to study math. They would apologize to him. They explained, once again, that if you do not possess a college degree, you cannot enroll in a postgraduate course. The boy would leave. It was fairly certain he would turn up again in a few weeks, with an unchanged plea.

Eventually, a well-known epistemologist from Argentina passed through IMPA. He would call on his friends, the Avellanedas, in Búzios during his visit, and when he did so he had some advice for one of the sons of the family. This epistemologist had heard that there was this 'crazy guy' who kept rolling up on the IMPA campus, asking for a place on the program, despite an evident lack of qualifications. The epistemologist had a few things to say. "Stop this thing." "Go to College!"

In 1977, Marco Avellaneda left Búzios for the University of Buenos Aires.


Downloaded by , IP 3.235.228.219 on 2022-03-05 02:37:2

MARCO AVELLANEDA

It's May 2013. Ensconced in the Four Seasons, Buenos Aires, on a family visit, Marco Avellaneda is a Professor of Mathematics. His office is on Mercer Street in New York City. That's the Courant Institute of Mathematical Science, the number one institution for applied mathematics in the United States. He has been inundated with awards for his contributions in mathematical finance: weighted Monte Carlo methods; Avellaneda's beloved entropy; disper sion models applied to correlations between single stocks and indexes; an uncertain volatility model that rocked. He wears all these achievements lightly.

"In France, I was okay; I got good grades, but no one told me that I was mathematically inclined and I didn't know it myself. What happened is that, in France, the idea or the concept of *being* mathematically inclined *existed* somehow."

In the course of our conversations, he often returns to ideas of 'floating' to where he would be most successful, letting himself go 'as if in a river,' an awareness that his environment strongly influences him. He employs a familiar conversational style, at some points almost confessional, and fittingly the flow of the interviews goes to where they will be most successful. We begin in Paris.

"As a young boy of 12, when we arrived in Paris, I found that the environment was very much conducive to the exchanges of ideas and we had very good teachers in the high schools and middle schools. There were a lot of things going on politically because it was the end of the De Gaulle era. The French were beginning to feel more wealthy, people were starting to question the system, they were emerging economically from the War, and people were feeling a little better off and were dedicating themselves to ideas and discussions".

As a person who was a fairly good student, Avellaneda considers himself lucky enough to have been influenced by that environment, even though he came from South America. Although it wasn't obvious to him that he would be a good student, but it was 'kind of cool' that you weren't penalized if you were a good student in school.

Avellaneda notes that traditional French guardedness toward the national curriculum was even more evident then than now. He attended the Lycée de Sèvres, a publically run international school which required its students to be submitted to both a French and English education.

"It was a public school that was indistinguishable from the French lycées; we were pretty much exposed to French culture all day long – they called it a special section. It was interesting meeting the other students from Eastern Europe, from Africa.

"Paris was the center of UNESCO in those days, so there was a lot of diplomacy going on; don't forget, it was the Vietnam era, so there were the negotiations in Paris – it was much more important, diplomatically, then than perhaps now. Then, in May 1968, you had all the politics, the cultural revolution coming from London, the swinging 1960s, the bands, the rock and roll, so we were exposed to a lot of cultural things and I was just lucky for being in those formative years – there were a lot of lessons and I could absorb all that."

Avellaneda's parents were "very young" diplomats who thought themselves lucky to be in Paris after coming from South America. "The job of a diplomat in UNESCO involved having to greet different people involved in culture and art from member countries, so we had artists, we had Astor Piazzolla in my house, we had theater people, people telling us about different arts, television education that was just starting, so my parents were very young and enjoyed those years tremendously."

By and by, the young Avellaneda discovered he also had a flair for mathematics.

"In France, I was okay; I got good grades, but no one told me that I was mathematically inclined and I didn't know it myself. What happened is that, in France, the idea or the concept of *being* mathematically inclined *existed* somehow. I remember I had a wonderful math teacher, Monsieur Attas from the French International sections; he'd always give us very long multiplications and I always got them wrong, so I was a fairly mediocre math student when I was finishing elementary school."

"In 1968, I was 13 years old and I helped, of all people, my mother because she needed to enter the Sorbonne. I don't know, she had the intuition that I was smart enough to help her with math and she gave me some math books with letters – with algebra," recalls Avellaneda. "I had never seen algebra before, but there were these television shows in the afternoon, teaching people electronics, electromagnetism, or subjects for electronic engineering technicians, so I saw these letters, although I didn't know what they meant. She gave me the book and I started reading it; eventually, I said 'Oh mom, this is very easy – this is a quadratic equation with two roots and you do this and that…' and I discovered I was very good as long as I didn't have to use numbers! I was good with letters."

Upon returning to school, Avellaneda had no problem with math, and got ahead of the class very quickly. The most taken aback was the teacher, Monsieur Attas, who finally recognized that the Argentinean student was good at math. "He was a little bit shocked; he must have thought: 'At first, he was average and then after the summer he comes back and he knows everything!!?' "

The brush with math created a hunger, according to Avellaneda. "I started buying books in the bookstores in Paris. In those days there were a lot of used science books in Chez Gibert and Boulevard Saint Michel; sometimes I didn't even buy them, I just stole the book, because I didn't want to spend money on books – I wanted to keep my allowance for

Downloaded by [illegible] on [illegible]

other things! But I had a collection – when we left Paris I had a big box full of books. Mostly, I was interested in it because it was a fun thing and it had a certain status, even with the girls in school – if you were good in math, you got some attention, you were different."

"It was strange," reflects Avellaneda, "and, contrary to what people say now about jock culture, the French were anti-jock, a jock wouldn't get anywhere, but if you were good in literature or okay in math or knew some politics, you could always get to talk to girls – and those were the kinds of things that I specialized in! We didn't know much politics but we could carry on a conversation, try to look serious – but in fact we were very naïve!"

The Avellanedas left Paris in 1973 for Brazil, following his father's retirement. It was there that Marco completed his high school education. The overt political awareness of the French years was replaced with the reality of living under a military dictatorship, no matter how benign. "After the coup in 1964 that toppled the Goulart government, there was not a lot of *politics*," Avellaneda emphasizes, "but there was a lot of culture, because the Brazilian artists and the Brazilian politicians put all their protest into musical and cultural movements which people could not say was outright speaking against the government! They were 'speaking to freedom' – Caetano Veloso and Gilberto Gil were exponents of those years. My parents knew Jobim – we were pretty much imbued in those years, the family.

"I must say that those years were not spent a lot on mathematics but we were having a good time, learning how to surf, how to communicate with people in Brazil, and meeting all sorts of beautiful people. It was sort of like a buffer between Europe and what I would do later on. I had no idea that I would go to university; it was very much a continuation of the swinging 1960s, but in Brazil – with the Ipanema beach scene and everything.

"I would say that I was very, very lucky that I had such good schools and good teachers in Europe because I was pretty much already imbued with the idea that people did great things. Although I was hanging out and surfing in Brazil, I had tasted the apple, had already seen, even at that young age, what people could do.

"When I was in Brazil, the Brazilian beach culture was really intense; we surfed, we partied a lot, but I knew in my mind that there was something else – there was more than just beach and parties. I didn't know what it was then, but actually it was Europe; I had already been touched by the bug. I was very strongly bitten by the bug of mathematics and was pretty good at math – even then I could carry on a serious conversation,; I even got a job as a math teacher at the French lycée in Rio, but then I quit because I didn't really know why I wanted to be a math teacher, except to make money."

The 1970s in South America were a defining period, economically. Brazil experienced exceptional growth, which sowed the seeds for problems in the 1980s, while Argentina entered a period of decline in manufacturing, per capita income, and standards of living – a great contrast there. Avellaneda was asked whether he was aware of these economic shifts at the time.

"It was easy to think in those terms because both Argentina and Brazil at the time were developing," he recalls. "They were still using the old 'substitution of imports' method, which

goes back to just after the War; but they were developing local industry and local manufacturing that were basically very uncompetitive – it was a very unglobalized world."

Differences were pronounced between Argentina and Brazil. Avellaneda describes how it took a long time to go from one country to the other – not only physically, but also mentally; the two nations didn't see each other as having the same culture, quite alien to the contemporary view wherein South America is seen as an economic region, an identifiable bloc. The perception then was that Argentina was a very wealthy place, a small country, population-wise, with a lot of agricultural business. Brazil, it was thought, was going to be suffering from the pains caused by the explosion in demographic growth, urban migration, and a critical problem with poverty. "So that," exclaims Avellaneda, "brought us into the emergence of politics, of protest, and so forth. "

Governments conducted experiments on how to develop, and these experiments started with currency. There were strong currency controls between Argentina and Brazil,

Downloaded by [redacted] on [redacted]

Downloaded by [illegible] on [illegible]

which then, as now, were each other's greatest trading partners. "So, living in Brazil but having relatives in Argentina, traveling as a young person, the first question that you ask is: 'Where is the peso versus the Brazilian currency?'

"The Brazilian currency had many names – they would change names, add more zeroes, and it was the same thing with Argentina. We had a decline. In Brazil, the story was that it was a military dictatorship that was based on the development of the energy base of the country; building hydroelectric plants, the development of the Amazon, suppression of protest from workers, and the construction of a system of roads and a set of railroads, which connected Brasilia (which had become the capital in 1959)."

The Brazilian Miracle saw the country's economy growing in leaps and bounds. "We knew a lot of people from the stock market who made a lot of money. My first contact with traders was at the beach; friends of my parents who would come up in beautiful cars – nice guys, fast-talking, making money in the Brazilian market." What brought it all to a halt was the oil crisis of 1972, in protest against the US support of Israel in the Yom Kippur War and other obvious factors; the Arab countries decided to take oil to whatever price they thought would hurt."

Brazil had no oil – they were a net importer of gasoline. They had reserves that they didn't exploit, instead giving licenses to American drillers. "Yes, they needed the gasoline. I'm not an energy expert, but the cost of energy was factored into the Brazilian growth model for the economy that went from 1968 to the mid 1970s. In 1973, it all started crumbling, so we saw the whole miracle, the stock exchange, slowly vanish. A lot of economics was just in front of us."

On the other hand, Argentina was going into what Avellaneda calls its "Peronist Baroque" stage, where they were "shooting people in the streets;" they had their own problems and they were transitioning from the old. "They could afford very expensive unions and labor costs, because it was a very small country and very rich. When this inflation crisis hit the United States, everybody paid the price.

"It is a fact that whenever we have a strong shock to the cost basis of developed economies like Europe and the United States, the developing countries that were commodity producers were immediately penalized because the price is set in Chicago, so these countries live in a boom-and-bust cycle. The idea there was to take the boom years and save and equip yourself with industry to export, which George Soros explains very well in his book, *The Alchemy of Finance*. There is one chapter that is dedicated to how to get away from that cycle, of being a slave to the cycle in the developed world."

It was ever like that – going back to the 1880s, when Argentina borrowed money from Barings and never returned it. The point here for Avellaneda was that Brazil made better moves, perhaps because it had a more strict government, like Chile. They developed their industry in a more organic way. Argentina continued down the spiral of not being able to use the wealth from the agricultural sector to transform the economy. Argentina is like an Australia, if you like – it's a small country relative to its surface area.

"We knew all this; this is why, in South America, mathematics and pure science never had the same appeal as economics. So, I was hanging out in Búzios with wonderful guys with yachts who were all stockbrokers. In my mind, it was like, 'Gee! Should I be a stockbroker?' "

There were no mathematicians to take as role models. "the only guy who I knew was a mathematician in Brazil was the son of a famous painter, Portinari, and he was at IMPA. There were no mathematicians in our circle but I knew I had the gift. So, when I went to university, I went to study mathematics. It's the thing that I knew better and I just fell upon a group of professors in Argentina who were absolutely top, top, top rate. They were essentially all Spanish émigrés from the Civil War. They published a lot and they were really good mathematicians. The rest, we compensated for with enthusiasm! We were young and ready to learn."

"I believe I am a mathematician. I call myself a mathematician, just because mathematics has defined my life since I was 13 years old. So, what I found in mathematics when I was 13 years old is not what I find in mathematics today at all."

When you're a teenager, a preteenager, Avellaneda avers, you use mathematics to isolate yourself from your brothers and sisters when they are making noise and you want to be by yourself, have your own little world. Then, as you grow up, you start to see that there is structure and that this structure is very interesting because it is axiomatic.

"I think I'm not the only one to say this, but I think a lot of epistemological scientists and psychologists say that our lives somehow mimic the development of the mathematical mind – it follows the development of mathematics to a certain extent." Mathematics, being axiomatic, starts by defining things. "It's like, when you are a baby you start putting names to

"My first contact with traders was at the beach; friends of my parents who would come up in beautiful cars – nice guys, fast-talking, making money in the Brazilian market."

things; a young child will say: 'This is a telephone,' 'This is a coffee cup,' 'This is mother,' 'This is father.' When mathematics was reorganized, and logic, by Bertrand Russell, by the Bourbaki School in the early 20th century, the idea was to redefine mathematics as an axiomatic thing. When I was young, that had an appeal to me because I lived in France and everything was supposed to be structurally well defined."

As he became more professional in mathematics, Avenalleda started enjoying the adventure of making analyses and tweaking, not just the logic. "A lot of mathematics that I came to learn was mathematics that took a lot from physics, and then it became sort of clear that mathematics is really essentially, to me at least, a sophistication of sciences that arise from other areas. For example, Gauss was an astronomer, and Newton was also a person who did the physics of his time. He was able to reformulate what people knew about gravity after studying for years and years the work of Galileo, Tyco Brahe, and other works, and then deciding to formalize it.

"Why is the formalization of science as mathematics important?" asks Avellaneda. "Because it makes us think faster, right? Once you know that this is a diffusion equation, well, it's a diffusion equation. There are many phenomena in physics that come to one equation, the diffusion equation or the wave equation, or the fact that linear algebra and matrix theory are regularly used in quantum mechanics because of the eigenvalues and the eigenvectors.

"All of a sudden, you start discovering – but this takes being in graduate school – that the beautiful French Bourbakian edifice of mathematics is really some re-elaboration of the fact that it's all about science, it's all about

borrowing from actual observation. Pythagoras' theorem is from a guy who wanted to get from point A to point B; he was a sailor, so he figured out how to calculate the distance with two reference points – and that part of mathematics is what I lived from my mid-20s until now. After seeing the whole edifice, [I was] able to think about it and the structure, understanding that this structure is nourished by observation, by science, by economics, a lot by physics."

By the time Avellaneda came to New York University in his 30s, and even before that, in graduate school, he somehow always gravitated to the physics department, the chemistry department, and the economics department, and in his own words "got distracted back into science." "So, then I chose to do some pure mathematics, but every time I was just fascinated with the modeling; the idea of mathematical modeling is very easily said. Emanuel Derman wrote an entire book about that, about what modeling means, and I think that mathematical modeling can be like Einstein is mathematically modeling the universe to very small things.

"It's not something that students appreciate – that as you grow older, modeling is what remains. I'd rather find new ways of modeling reality than working inside the structure of mathematics, and when I say that, it's not ideological, it's just that I

float to where I think I will be more successful."

"When I made the move to the United States, I really was in love with mathematics. I didn't know what I wanted to be when I grew up. I thought, after the undergraduate school, I could work in a graduate school and make some money teaching. The University of Minnesota took me on a stipend. I originally applied to Berkeley but they didn't accept me. The university selected me because there was a very strong connection between Minnesota and some very famous mathematicians from Argentina.

"I got to Minnesota and I never took a probability class; I think I took one topic in probability – despite which, in the end, I got a PhD in probability! Let me tell you why: the American system is based on liberal arts and sciences, understanding a bunch of subjects. In Argentina, we were, for four years, doing very advanced topics – we started with the standard stuff but we ended up with functional analysis, differential equations, things that are not seen in graduate schools until maybe the second or third year. We were exposed to things like the Polish school, the Hungarian school of analysis, things that were all fashionable in mathematics."

When he came to America, Avellaneda found that no one applied anything. "When I got to Minnesota, I found that the courses were relatively easy, mathematically, but I also found myself on a campus with a top chemical engineering department. It's very modeling based, you know, Brownian motion, and particles and emulsions – it's very model related, very mathematical, and very related to diffusion. It's a huge campus and we went to seminars in all the departments; we walked from one department to the other and just sat down in a chemical engineering class or an engineering class – that's what I did all day long for four years. While I was taking classes, I would just go along to the economics department – Gerard Debreu was there and he did more equations than I did … like wow!

"We did one year of economics and that caught my attention because in those days we were very quiet in seminars, we just listened. But in economics, we fought incessantly and I said to myself that this must not be

Downloaded by [redacted] on [redacted]

a good field to be in because everybody's fighting; little did I know that I was going to end up here!

"What they were doing then in economics was developing general equilibrium and finance, Kenneth Arrow, Gerard Debreu, and so on. Financial economics seemed to me to be a very dirty field, with very angry and belligerent professors. So, that's why I stayed away for a long time; I dedicated myself to applied physics when I moved to Courant. My PhD was in Brownian motion on manifolds, my swansong on a connection between differential geometry and Brownian motion, which has actually been applied in finance by Lane Hughston, I once went to Merrill Lynch, trying to get a job as a consultant, and I was invited to talk about an interest rate model which was actually Brownian motion on a manifold, so I said: 'that looks familiar!'

"When I came to Courant, I said I will never do Brownian motion again, I'm going to do physics, materials, waves – that was the fashion at the time – composites, and I spent ten years doing that. I was a member of the American Physical Society, the American Society of Physical Engineers, and the National Center for Atmospheric Research, as a representative of NYU. I did a lot of applied science, I wrote papers, and I thought I was good; I wasn't that good, but I was pretty good in applied science because, for example, that's when I learned about the British style of applied math…

"The British were as you'd expect: the French are Descartes and the British are Locke and Hume. The British are empiricists; they observe something then fit an equation around it – continuum mechanics is a British field, pretty much. In Minnesota, we studied continuum mechanics, stresses, strains. All of a sudden, I thought to myself, well, there's a big tradition in England because of thermodynamics and so on; the British were applied from day one, they didn't formalize mathematics. When I was in graduate school, they said: 'That's fine, all your spaces – Sobolev spaces and Hilbert spaces – but you don't need all that, you just need to be able to think and contextualize.' Well, before modeling, I learned about contextualizing because I knew that when I wrote, my readership didn't care about the theorem, they cared if there was something that they could discover from the math – and then I started fine-tuning my message that I wrote to contextualize more, the British way of doing applied math. You can't define the world by axioms every time you start a paper.

"That is how I got into applied math. Then, applied math was very important at Courant – we were, and still are, the number one applied math department in the world. Well, we had a style and, for me, you know what Courant's style really is? It's the German style. Because the Germans knew all the extractions, all the logic, but they were extremely practical; the Germans always believed in being overqualified, right? So, that means that if you know a lot of mathematics, then you can teach high school! So, their idea was that mathematics can be applied to anything, so let's just apply it to wherever the money is, the grants, the air force – we're German, we're sons of Courant – and that took me to the 1990s."

Avellaneda spent much of his time in the 1980s and early 1990s working on grants from the army. It dawned on him that, as the need to beat the Soviet enemy was disappearing, so there was less money and less interest in fields to do with defense. A friend was telling him how well he was doing on Wall Street. Avellaneda had heard about Black–Scholes and recalls being in a faculty meeting where members were discussing the department's need for money: "Why don't we teach some options, you know Black–Scholes…?" Avellaneda suggested, and somebody said: "What's that, and do you know somebody that can teach it?" "I said I could teach it, I could learn, I knew a few people who knew about Black–Scholes," said Avellaneda.

"I used to bump into my friend in the sauna at NYU and he was trying to figure out if Black–Scholes applied to interest rates, because up until then it was about stock options or options on equities. 'Do you think it applies to LIBOR swaps?' he asked. I was doing physics, he was working for Lloyds, and he went to work and would code that up or got someone to code. Even though I didn't have a formal foundation in financial economics, I had a bit of street smarts, a bit of American inflation education and money education, so I thought, I can do this – this is my language."

The building process towards Avellaneda's full immersion into financial math began in 1985 through to 1993, when he taught his first class in finance at Courant. "I have to tell you that New York City in the 1980s and Wall Street then was a glorious period, and I got there exactly at that time. So, by now, you notice that I'm very influenced by my environment – I always was." Even though he stuck to Courant's German applied science, Avellaneda started getting invitations from friends on the Street to join them; he declined, explaining that he was a scientist, so no. "I was doing pretty well. In those days, the difference in income between a Wall Streeter and a non-Wall Streeter was big, but banks did not yet have those heavy teams of derivatives traders, it was more like a lot of futures traders; a couple of guys doing swaps and mortgages had just started up at the end of the 1980s.

"I caught 1987 in New York, and that was really a stock market crash and didn't really affect banks all that much until the early 1990s, when the crisis sort of spread. I was pretty much in the mix; I remember where I was when the stock market crashed. There were some people in my office listening to the radio: 'Oh! The Dow has dropped 500 points!' 'Is that a lot? I don't know…' It was the biggest drop ever!

"After seeing the whole edifice, [I was] able to think about it and the structure, understanding that this structure is nourished by observation, by science, by economics, a lot by physics."

Downloaded by - To view the rest of this article please download

"I kept in touch with my friend Jay Lovatelli, who was a young, very talented guy for trading in those days, so that is how … so when I started teaching, it was very funny because, I went to a party, I asked a guy from Stern would he recommend a good book and he gave me Darrell Duffie's book – everything is in this book, "teach Duffie," they said. So, that first course was built around Duffie and then I told Jay Lovatelli,; he said: 'First you don't want to work with me and now you want to be a teacher of this?' He found that weird. He said that he thought I was going to come and work with him. He was at Lehman Brothers at the time. He said: 'Okay, I'm going to put you in touch with two guys from Lehman who are the derivatives wizards here …' – what would be called the quants now – '… and go out for dinner with them and see if you get along …'

"They took me out for dinner in the fall of 1993, and then they said: 'These are the notes of Mark Rubinstein on exotic options; we don't understand them. If you're going to teach, can you teach this?' "

Armed with Rubinstein's mimeographed notes on exotic options and Duffie, "… which was basically about risk-neutral valuation, present value of random cashflows, completely neoclassical microeconomic theory applied to financial economics," Avellaneda took these two things and created the class. The class was oversubscribed: over 100 people – all traders.

"Lehman had spread the word that this guy was going to do this in a way that they would understand, plus there was the potential of hiring people from NYU. In those days, we really didn't know much. Could Rubinstein's tree be applied to interest rates? People were just discovering

the yield curve on one hand and were trading a whole package of things, a whole basket of rates in every option. At the same time, you had the exotic derivatives, the barriers, and nonintuitive convexity properties, and all this was described in the language of extensions of Black–Scholes. Now, since people worked off of trees, you can imagine that mathematically, in terms of modeling options off of trees, once you start to put on a lot of bells and whistles, it becomes impossible. So, the idea of thinking in terms of paths, Brownian motion, throwing in a little PDE – the interest was so great in those years."

The first big growth in derivatives in the United States was fixed income, as in the aftermath of 1987 people needed to know about getting cheap financing and working from that angle until the equities took over by the latter half of the 1990s. In Japan and Asia, they had a lot of warrants and long-dated equity options. Foreign exchange was important because in the age before the European Monetary Union: "There was the mark, there was the franc, the peso – how did they trade the Swedish krona for the US dollar for example? Well, the idea was that you had to think about the option on the Deutschemark, so the krona is off the Deutschemark; England was always very independent and it still is. I learned the craft of foreign exchange through a consultancy with Indo-Suez, with Nassim Taleb. See I met Nassim Taleb and he said: 'I'm going

to make you a financial consultant, so this is going to be your boot camp and you are going to learn finance!' I had good teachers!"

"I met Taleb in 1994. I met Wilmott in 1994. I met Duffie, I met Raphael Douady and we were doing seminars. For example, Duffie, I met at a conference in Princeton in 1994 – we invited Duffie, we invited the chairman of Bankers Trust, we invited Nassim Taleb, Peter Carr was there; early on, everyone was looking for what to do – Dilip Madan, as well."

The now infamous Nassim Taleb had a lot of training experience but Avellaneda explains how he also had developed his own private mathematics: "He came to me for a little bit of help to formalize things, to make sure that he wasn't writing nonsense. He told me what he meant and then he would say: 'Is that how you write what I mean?' And that was fantastic because I got to learn a lot from him about path dependency, the greeks don't work – for me, it was great. I said to him: 'Nassim, don't worry about math, just do whatever you want – the math is not that … applied math is whatever you want; you are trying to describe reality, so dare to be different. Otherwise, we are all going to be the same, we are all going to be writing Bourbaki again.' So, we became very good friends. He was always a great influence on me because he's a very friendly and simple man on a personal basis; on a public basis he is the eternal provocateur because he believes the only way to get noticed, to do good television and good media, is to come up with strong ideas! He's good at that, and he's made some important points, and that's why he's famous in the field of ideas."

Avellaneda knew Nassim Taleb, who came to him with a shoebox full of the pages of his first book. "He asked me, among other people, if I could edit this book with him. Dupire and Douady were a couple of the others. I must say that I wasn't one of the most academic helpers; I would just sit and ask questions, and what was important was that I always showed him my models – a particular model that I had started calling the uncertain volatility model – and he was very, very, very fast to, kind of, I wouldn't say he cautioned me against modeling too much – he wasn't a mathematician anyway; whenever I found something right, he would say: 'Of course, of course, of course, of course. That's obvious.' If he didn't agree, he'd say: 'No! No! No!' That sort of thing.

"His thesis was about transaction costs and he had a beautiful idea that transaction costs are different for market makers and to nonmarket makers who delivered orders. I had a paper on transaction costs. I want to think that he was a bit influenced by my paper, which was influenced by Paul Wilmott, who was influenced by some other people in the United States, and Nassim did his bit on the same thing about Knightian uncertainty and model risk. Nassim was the king of model risk; by accident, I discovered model risk – Paul did too. Those years, the mid-1990s, was when model risk emerged. I was on the mathematical side of it – I did the uncertain volatility model. Nassim talked about Knightian uncertainty, Paul and Terry Lyons also did uncertain volatility

Downloaded by [redacted] on [redacted]

MARCO AVELLANEDA

for rates and publicized model risk. Paul was a continuum mechanicist; he knows PDEs and everything, so I think that was an exciting era for modeling…

"We were all consulting – we were seeing how much our theories would impact or not, and there was a bit of salesmanship as well because in those days traders did not know anything. If a trader liked you, he'd say: 'Okay, let's go have a bottle of wine,' and then you went to Smith and Wollensky's in New York and got half-drunk together, then ask: 'Are you going to hire me as a consultant…?' 'Well, I don't know!' But at least you shared a lot of knowledge."

Avellaneda recalls that it was a lot of fun; while giving a science seminar in Paris on the uncertain volatility model, a French trader said: "You've got to talk to this guy in New York who is my boss, who runs the New York book on currencies, who is a friend of Nassim's."

"These were very much Staten Island guys, desk managers, businessmen. 'Well, yeah, okay,' they'd say. 'Maybe we'll hire you.' They hired me and then told me that I had to program. Truth was, I didn't know how to program! So, I had to teach myself. It was a cycle of business and you had to be very open minded because derivatives were not understood in terms of their pricing or their modeling. However, there was a lot of money to be made."

In 1994, the Mexican crisis occurred. The currency devaluation that took place in Mexico as a consequence of government policies of dollar parity that were inefficient was also known as the Tequila crisis. "I had begun to live finance a little more," recalls Avellaneda. "I had begun teaching it and was talking to people. In those days, we got the option quotes from the New York Times – at least, I did because we did not have a Bloomberg terminal. Telefonos de Mexico (TELMEX) was the most traded stock – the Mexican phone company. So, I have an early paper which was on that because it was the biggest open interest option at that time. The Tequila crisis was very interesting because it showed for the first time how you could get correlation between emerging markets. So, the Tequila crisis really affected Argentina and Brazil because it affected, in particular, the beginning of the Menem government, which was meant to be a fairly market-oriented government. They had to do some measures to avoid repetition of what happened in Mexico, so, with the recession, in those days people were very worried – both in Sao Paulo and Buenos Aires – of what they called the hangover. So, they had the Tequila crisis and the Latin American hangover!

"Market-induced correlation was a theme I picked up on very early. We had discussions about that in New York because we saw the effect that Orange County had had in the early 1990s, the structured products and how those affected the ratings of other municipalities, and the municipal market was affected by the default. So, this idea that one issuer or one country could have, if you will, 'guilt by association' was something I was very interested in. I didn't know how to model it yet but that, I think, influenced me a lot and got me more interested in how Latin American countries work. So much so that I went to Buenos Aires, invited by IBM and the Stock Exchange, in 1994, to discuss derivatives models. There were still a lot of local dealers in Argentina at the time; the banks had learned how to do derivatives, invest in Brazil, do foreign exchange, and so forth. But, as a result of the Tequila crisis, the Argentinean financial sector started to disappear as the local players were taken over by the US banks."

In the early 1990s, Avellaneda saw a lot of people coming back after 1987 and getting into fixed income. The big thing with fixed income in the early 1990s was that it was difficult to model because of the yield curve trading.

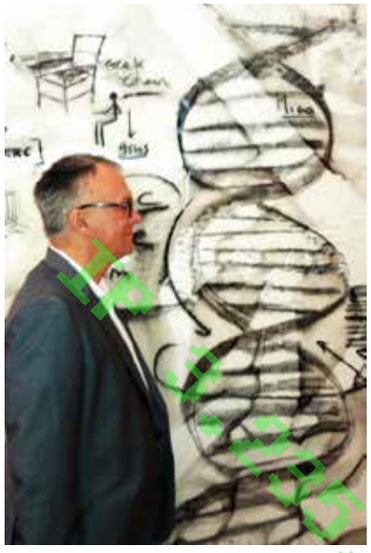
"People didn't understand the yield curve; they thought it was a completely different world, combining the term structure of interest rates with equity, with volatility of different buckets, and how they are correlated. We did a lot of that when I went to Morgan Stanley and worked as a consultant. Then things came back because after the crisis things became dollarized. Secretary Brady had this program where they restructured all the Latin American debt and they issued the so-called Brady Bonds, which were bonds that had a guaranteed principal and coupon. Argentina and Mexico restructured their debt with Brady Bonds in those days. When I went to Morgan Stanley I was essentially a quant for Brady Bond derivatives; I was part of the whole swaptions organization – which was called the derivatives products group – but my personal interest, where I got some of my models to work in the market in a more specific way, was with very exotic structures that were marketed alongside Brady Bonds. For example, you could have knock-outs, knock-ins on yields on internal rate of return – very nonlinear. There was always a marketing scheme, always a way of getting the customer to basically get interested in these bonds that were pretty plain vanilla but allowed people to trade them rather than just sit on them. Morgan Stanley was very good at that. These were dollar bonds; Morgan was unlike J.P. Morgan – which was a very international bank and didn't mind foreign currencies. Morgan Stanley at the time was run by a guy called Paul Daniels. He was a Brit, but for him it was all about the dollar; in emerging markets they touched only the dollar.

"Equity people participated in the IPOs of the famous Telebras IPO, Brazilian Telecom, so the American banks jumped into helping people issue debt and stock in the mid 1990s. I was able to see that market and try out some of my models that I had developed – in particular, one that Paul Wilmott likes very much, called the uncertain volatility model. I was trying to make it work for all sorts of different scenarios – for option pricing, say. It was a very interesting period; in the early 1990s derivatives really started to come into their own, but people didn't really know very much. Looking at the old finance papers, looking at some math, some statistics, and I was very happy … it was a good modeling period – LTCM, the Argentine crisis, and the dotcom bubble. First thing I remember about LTCM is from when I was at Morgan Stanley, and it was very severe, the way it impacted some of the other businesses. That comes under the heading of contagion, contagion from other countries. Same with LTCM, which was basically a contagion associated with the devaluation of the ruble, and that again appears in all sorts of spreads all over the world, widening, and LTCM was a convergence trader. But I learned about convergence trading, the idea that you could wait for two things that were away from fair value to come back, and it was a pretty intellectual trade at the time.

"The Argentine crisis – well, that's very interesting because Argentina is a mess; they're brewing their next crisis now. For us Argentineans,

we know everything about foreign exchange and currency controls, but the Argentine crisis was essentially like the ERM in Europe or for the pound multiplied by 100, because there was meant to be a parity between the dollar and the peso. But the government kept borrowing money and they needed to pay a lot of interest in pesos – there was a huge difference between the rates. You could basically have a peso account and a dollar account, both fungible, but peso accounts paid a fortune, and even onshore dollar accounts. At some point, people suspected that this was untenable from the point of view of the government – that those interest rates were just way too expensive. Then there was a very interesting element with O'Neill, the Secretary of the Treasury under Bush in 2000; this was the former CEO of Alcoa, very American mid-western puritan, shall we say. He decided that he would not bail out Argentina. Then Bush went to Brazil, doing a fact-finding mission, and somehow the Brazilians charmed the IMF and the US Treasury. The Brazilians were also in a great deal of trouble and they devalued in 1999, but the market kind of gave Brazil a pass. This was correct in retrospect; the market was right in giving Brazil a pass, because Brazil had done a lot to improve its economy and at the same time the market sort of forced Argentina to default by not refinancing the debt. Argentina fell off the map from that point on; there was no more finance there."

During the merger of BNP and Paribas, Avellaneda was hired by Jean Michel Lazzari, who was a mathematician and a friend of senior management and had worked with Bruno Dupire's team. Dupire had already left Paribas, but with some of the fixed-income traders in Europe, Avellaneda



became familiar with multi-asset, yen, complicated curve trades and risk calibration of rates, interest rate curves, derivatives, swaptions, and the volatility cube, having seen a few examples during his time at Morgan.

"European banks were much more cowboy in those days; the Paul Daniels and the Morgan crowd were about relationship banking, white shoe, only do juicy deals, don't take too much risk, and take the right risk. They were good bankers; those guys in the 1990s at Morgan were very very good – they knew they had a name, they had a desk, they had potentially a franchise like Goldman Sachs. But as Morgan Stanley moved into the year 2000, there's the arrival of the European investment banks like Paribas and maybe Barclays for a while, and those guys wanted to compete. They had the network of distribution of derivatives, they had no restrictions between their investment banking and retail banking arms, and they could use their own client base, so as a result they became much more aggressive in marketing derivatives, both as originators and as clients of the more bulge bracket banks like Morgan Stanley.

"There was a lot of work then, helping the French banks to establish their models, the Belgian banks to establish their models. Britain was different, because Britain had always been more advanced. But the continent was really tooling up; they wanted their own models to price and to keep in their books very exotic deals that were shown to them by Goldman or the bulge bracket firms. I worked in that and continued working in that until 2005–2006. The European banks saw their opportunity of participating in the capital markets and investment banking at the same level as the American banks and the British banks, so the Santanders and the BBVAs and the Société Générales all of a sudden had huge trading floors, and they needed quants. I remember Raphael Douady in Paris ran a quant floor and he had a lot of good problems. Looking at the European side of derivatives as it developed was a very interesting experience. Everything was rewritten, adapted to the system, and of course the French, being the good mathematicians they are, developed a lot of software in those days. At that time, I experienced a break with my physicists and started spending a lot more time in the markets. There was a little price to pay there, because you always have to be a good member of the community, so finance always took a little toll. I felt I was slowly swerving full time into finance, and by the beginning of 2000 I was just doing finance."

Uncertain volatility came before the dotcom bubble. For Avellaneda, the dotcom bubble was spectacular because people were quitting Wall Street jobs to join startups. "Wall Street had to give up the dress code because the startup people were going to work in jeans; the suit was abolished gradually – first on Fridays, then other days. So, the job of being a banker was not as glamorous. For me, I was back at NYU; I was now consulting, I was in the middle of learning a lot of things, but I started to do some trading myself, some equity trading, along with everybody else, with the taxi drivers – I was not very original!

"I knew Nassim, who was also in the dotcom bubble. He had quit his job but somehow he was back

Downloaded by [illegible] on [illegible] 02:37:2

"After seeing the whole edifice, [I was] able to think about it and the structure, understanding that this structure is nourished by observation, by science, by economics, a lot by physics."

on the scene, and we started doing something from the uncertain volatility model, into something called maximum entropy. In the uncertain volatility model, you don't know which model to use, but then you have to choose a model. To choose one, it's like choosing a probability; when you choose a probability, and you have many because markets are incomplete….I said, let's choose a probability the natural way, which is using entropy, because the relative entropy, or the Kullback–Leibler entropy, is the one that is closest to your beliefs. It's a little bit like utility maximization but on the probability side.

"I don't really believe in the way that economists use utility where they have this whole utility approach to general equilibrium. I think more in terms of when I'm going to price something; then, I've got some beliefs, some incomplete information, I price something that is appropriate, that is close to my beliefs, and UVM is essentially a range of possible beliefs, a range of probabilities – you're agnostic in terms of what you believe the volatility would be. With entropy, you are not; therefore, I did maximum entropy first as a PDE problem, and then it dawned on me that I could do it as a Monte Carlo problem, so therefore to higher dimensions.

"So, then I left PDEs because I said to myself, I don't need PDEs – I have the concept of maximum entropy, I have the concept of a model uncertainty, and I can implement it in higher dimensions. In 2001, in the aftermath of the dotcom bubble, I got my first job trading this model, in terms of applying it to dispersion trading. It was a time when everyone was making their hedge fund; Wilmott was making his hedge fund, Nassim was making his volatility fund, and I said, hey, you know I'm not ready to make a hedge fund yet but I have a strategy, so I started trading index options in the summer of 2001.

"I was trading through Enron, through that period. It was really exciting because the option traders liked the model and I went directly to work for option traders: a guy by the name of Charles (Chuck) Goodgall, from Gargoyle Strategic Investments. The firm was an option market-making firm; in the flow, they were upstairs – that means they participate in the flow, they close the trade in the exchange, but they are essentially providers of liquidity for block trades. They said: 'Okay, let's take Marco, put him in a little room, and he'll tell us what to trade.'

"I came up with these big sheets; I'd go to Chuck and I'd tell him that I wanted to sell the S&P here, September calls 25 percent out of the money, buy all these options, and he was fascinated: 'Like really?' Their approach, as with all good traders, was that they were going to try to really understand what this guy was doing because they wanted to do it themselves, and if it wasn't working they wouldn't understand why it wasn't working. They did that; I got a deal that I would partner in a subfund and we could part ways – they would keep the code but I could still use my code, It was a gentleman's agreement, and these guys in Wall Street provided capital. I stayed there in Spring 2001, all of 2002, and left in 2003.

"One of the things Chuck always told me was that when you do a model, you're very enamored with the whole thing, but there are certain parameters here that I don't understand. What if your beliefs change? You're great at transforming beliefs and options prices into a pricing measure, but what if the beliefs are different and the market changes beliefs? You still have an option position on it, so then what? That is what people call marking to market.

"You can have a great model, but then in the options trading situation you are mostly trading volatility; you are not trading delta and gamma, that's not what we do. In equity options you mostly are hedged, you mostly are trading 'Is 30 a lot to pay for IBM? Can you sell it at 35?' One of the things about dispersion trading is that there is a lot of vol and you can sell S&P index options at 25, which look very cheap, and I'm going to buy all the names and I think I'm making money. The idea that you could be selling options as the volatility came down, and they continued coming down and you were hedged, the traders thought that was good.

"These traders would not take propositions, they were strictly market makers. So, at the end of the day, if Marco is right, it's going to be a support for market making as the market becomes more efficient; if Marco's wrong, he's wrong – he's not expensive, we have capital and let him do it. I did it; I made money for some of the investors. I had trouble in the summer of 2002 because there was a crash in volatility which had to do with the analysts. The scandal with Blogget and Citibank was recommending bad stock to its customers; that was a very awkward volatility moment because somehow the markets really crashed, the S&P volatility went up a lot, and it was only when we went to Iraq in 2003 that it stopped – in fact it stopped in the fall.

"At the time, I got very greedy, more greedy than I should have – well, not greedy; options risk management is always complicated. My risk management was what it was and I had taken too many positions in November expirations through the beginning of the summer. That summer was very volatile, and on a mark-to-market basis we lost money – and so did I. Somehow, they lost money because vol shifted up and they were vol sellers at some point; market makers have to make money somewhere, so you are selling volatility.

"One of the things that I liked about this experience is that you're happy selling volatility; we used to joke that there's no reason to buy an option, you can only sell one! OR when we made money dispersion trading by selling index options and buying the names, we were asked: 'How did you make money?' Well, did you see the index after the vol

dropped ten clicks? Then they say: 'Yeah, but why did you buy the hedge when you sold the index option?'

The Gargoyles were very good; they got me from UVM to entropy, to multidimensional entropy, to trading options, but I started trading option portfolios before I started trading stocks."

"So, I'm sitting at the beginning of 2002 in my office at Gargoyles in New Jersey, and Josh Danzinger, the founder of Valere Partners, gave me a call. He was the head of structured credit at the Royal Bank of Canada – very smart man who is a chemical engineer – and he said: 'Can you come and help me? I know you're a friend of so and so and you can do this. We're running a book of CDOs at the RBC in London; I can't compute the deltas, it's too long, so can you come to London tomorrow?' So, he flew me in on Virgin. It was the weekend and he invited me to his country home. So, we went to Norwich with his family, and in the evening he said: 'Look, here's the problem: I'm a chemical engineer, I have this model that involves all sorts of default rates, and I'm selling a 100-name CDOs bespoke, so I need to have some kind of control on how I compute my deltas and all sorts of things.'

"I said: 'Okay, let's use maximum entropy.' So then I basically used entropy and relative entropy as ways of doing the perturbations instead of doing them by tweaking all of the parameters. The idea was, you have 100 names, you have to bump the curves and compute sensitivities to spreads. With maximum entropy, I could compute the sensitivities almost by hand once I had done the calculation – it was a sort of indirect method."

Avellaneda would then go to the desk and observe how they were participating in the credit market,

which he describes as, "very seat of the pants." The credit derivatives market that he had witnessed with Morgan Stanley in New York was mostly asset swaps, where the bank financed the customer buying an emerging market bond but essentially kept the bond as collateral and did not give the customer back the bond.

"What is an emerging market bond? It's a treasury bond plus the option to default. So, if I could buy a default insurance, then people started to try to price the default insurance and put that into the financing agreement, and that's how this market started. Morgan Stanley had zero models; Duffie had a model called the structural model; and then there was the old Merton model for credit, which was Black–Scholes.

"Black–Scholes didn't work because it didn't have a yield curve and then Duffie stepped in and said that whatever you did for fixed income is the same for credit; that was somewhat misleading, as we now know, but it gave people the courage to implement the models in Wall Street to manage credit portfolios. As with all businesses, it started back to back – I sell you a bond but I keep it as collateral. I finance it, and if you go bust I'll keep the bond and I have a recovery rate. But I'm going to charge you for that spread; I'm insuring you, and then I could basically buy protection in synthetic form from somewhere else. So, if I could buy synthetic protection and do a better asset swap than market, then I would be booking in profit. And that was the beginning of this business.

"Then came the famous lady from J.P. Morgan – her name was Blythe Masters. She was the queen of the CDOs – she invented the CDO. She ended up running commodities in J.P. Morgan later on, and got out of it before it was too late. She created the first J.P. Morgan CDO based on J.P. Morgan debt, corporate debt. That caught on.

"I could never write papers on credit, which meant to me that there wasn't that much science to credit; there was just a lot, I just couldn't put a finger on it – aside from the Josh Danzinger bit for RBC, there was nothing you could say. There were hundreds of papers – okay, this is the most prolific writer on credit, this guy, that guy, but these models were not based on data and were based on very weak intuition about what happens. They were essentially ways of marking to market illiquid derivatives. As I didn't have a view on illiquid derivatives... and the reason you were marking to market was because profits were taken on top of the models.

"I loved options on equities and equity derivatives, so I kept working on equities, but when someone asked me to do something on credit I never could do more than one or two papers on it. On something John Hull did, I tried to improve it, but I was already behind the curve, mostly because I don't think there was any good thing to say about those models. What was definitely missing was liquidity; that was the idea – how do you handle a market that is essentially illiquid and wrong-way credit? You're doing a derivative security with someone where if the product goes down, their credit rating also goes down.

"There were lots of elements … credit is a very touchy-feely thing … to give credit to someone, and the fact that these models existed, sort of opened the doors to engineers to enter Wall Street, doing credit by computer. It's like when you go to BMW and your dealer presses some buttons and he says: 'Okay, fine, you do have credit!' That allowed the market to leverage up, because you don't make money on bonds unless you leverage, so they leveraged and leveraged and leveraged until the whole thing came tumbling down. But I have to say that I never could get any traction on my thinking into credit, not that I didn't try. Now, I'm much more savvy on that and my angle is a liquidity angle.

"Credit is easier to handle in the repo markets. I did some work on repo for some clients and that's like overnight risk. I have an asset-backed security as long as I can repo it, then great. If I can repo it at the Depository Trust and Clearing (DTC), great – then we're good to go. I am going to take your paper as collateral, I'll fund you for a day, then we'll renew tomorrow. And I will know from the market how much haircut I'll need. That's how I began getting interested in these credit markets, from the short end, what can be put into the repo markets – if it can't be repoed, then it's more complicated. Then I became a finance person! When you give me a bond, my first question is not whether you can describe the cash flows – it's how can I finance it?"

"The idea of the data is important, if you look at derivatives – let's say credit derivatives, looking at

Downloaded by [redacted] on [redacted]

MARCO AVELLANEDA

it from outside math finance for a second. Before the crisis, if you said: 'Can you give me some data on credit default swaps?' you would have had none. Back in 1991, with the implied volatility of Telmex options, no one had a database; even now, if you want high-frequency implied volatility of stocks, because people are trading options at high frequency, it's very difficult to get, it's very expensive. The data, the idea of a full pricing of something, is very valuable because in any case you would be able to build better models.

"Our models are basically taking a few data points and interpreting them into some sort of pricing thing; like, say I can take the implied volatility surface and I can price an exotic by interpolation, with a weird strike or expiration date, but if you had the actual data of that and its liquidity … so that means that data and how to model liquidity are the frontier – how do you model getting out of a trade? If your model parameters change, if the models that you added by hand, either because the market now sees them differently or because you didn't calibrate them to begin with. So, yeah, the data is not a fashion; I'm not talking about Big Data and snooping, I'm talking about what can be better than having the history of all the apartments in the district, from when they were leased or sold for the first time, when you first buy or lease an apartment? I don't care what model people use, that's very valuable; you have economic cycles in it, etcetera.

"Quants have to learn that, and that is not an easy trade to learn because the quant model is very sophisticated from the point of view of probability, differential equations – you know mathematicians can't deal with data! If you go to a math department, a lot of people can write equations, but very few can write equations that fit data. I think that part of the mystique of math finance in the 1990s and the 2000s before the crisis was this idea that we could have interpolation models that work. Now, what we learn is that these models are interpolations that work in fair weather – that's the right word. When nothing happens in the ocean, you can draw a straight line from Newark Harbor to Penzance and say, you go in a straight line and you get there. But there's a storm in the middle, it's not the geodesic that works. You need to know the probability of that storm and how you will handle it, how can you get back to shore.

"Nassim Taleb's fundamental thesis is that all models are useless because they are fair-weather models, they work when there's no big model risk, no big parameter risk. Now, I'm not a person that doesn't like models – on the contrary – but I learned that you have to take a proper haircut, and you have to be honest about how you are going to shock the parameters. At the end of the day, what are the models for? This is the sad truth; there are models and then there are models for bankers. Models, we all know what they are, but models for bankers are models that you use to take to your P&L for making a sale at a different price than you're modeling. A model in a bank was always a consensual device that allowed you to mark-to-market deals that were made with clients or other counterparties. So, they'll say: 'Aha! My boss says I should use this model; he gave me a model, I sold it for more money than the model, now I want a bonus!' "

The fights in banks are always about which models to use, suggests Avellaneda: "When they migrate from one model to another, you have no idea – the bureaucracy is incredible, it's like the Soviet Union. You have to meet in committees and discuss the migration and answer the questions why, what's the big deal? The big deal is that you have a P&L shift! You have a P&L shift when you change the model, then accountants come in and say the price isn't that, and then traders say they don't like this model because with that model they made more money – so, it's the use of the model as an accounting tool to determine who made money and who didn't, and how much. The city of London is full of Lamborghinis that were made based on that.

"That's one kind of model. Then there's the kind of model that traders use to take risk. That's a different story. You give me a model like Black–Scholes; I have all the parameters, and I use data to perturb them like crazy. That tells me the range of P&L that I can have by holding this derivative, and then I have to make an educated guess as to whether, if I sell it at the proper price, I will have enough capital to survive for a while, and whether it will end up being a good trade or not. We calculate all the risk measures, to determine whether you will be in business or not. Or my dispersion model, which is about correlation trading – with that model, I should be able to determine the risk that the market will remark on correlations. It's frustrating to have a hugely differen t correlation. I have an idea of where I think things should be, that this is a good trade, but the model can serve as a way of finding not only the price, but also the uncertainty around that price. And to get the uncertainty, you need data to tell you what are extreme moves, what moves your underlying parameters have made in the past. That use of models is the correct, healthy use. The use of models to tell your boss that he owes you a bonus, is not a healthy use of models."

Avellaneda believes that banks continue to have these discussions about migrating models, but it's not something he wants to be part of. "I thought that these people were working for some sort of 'common purpose;' there's a model, sell it more than the model, and there's your profit. The problem with that is that these are all models for very long-dated stuff, on a PBO1 basis; on the curve you used to discount, you made a great trade, but next year if the curve moves, then you didn't make a great trade … but by then you're gone. That conundrum is very easy. It's complicated but I'll tell you something – credit valuation adjustments are in fashion now. It's a bit about how much should I take, should I say that I really made a great trade or should I discount with the curve of my counterparty, and then it's not such a great trade, so how much is this going to be profit for the trader and how much will be reserve for the bank? Because it's the politics of sharing P&L, that's not what models are for – they are not accounting tools only. Models are also, in fact, as accounting tools – they are very much, if you like, something to agree on. If we are going to price the whole book with Black–Scholes implied volatility, that's saying nothing. It's not a model that tries to give you an edge over the market or a better risk number over the market.

"I think that what we are finding now is this distinction. Emanuel Derman always talks about this – the whole idea of physics, mathematics, has been the idea of an underlying truth with a capital T that makes these models good, and that's been taken out of the culture. A model is a model – it came from this guy, but it doesn't have the same truth value as the nat-

ural sciences. Those words have been spoken before, and for me coming from the natural sciences, it was obvious to me from day one.

"When you model the price with a Brownian motion, it's not like modeling a particle of pollen suspended in water! One is the process of millions of small molecular hits; the other is, I have no idea what the price is going to be tomorrow – hey, let's make it Brownian! It's a different world. There's no microscopic reality. If there is, please let me know because I've been looking at this for years. That's what we're looking for; we're hoping that high-frequency trading may be more data correlated around the products that we trade, but that's going to get better control on understanding arbitrage and models, that's what we're looking for, but we're doing it as an exploratory journey. I would not run a bank with any of my models. I would probably use a simple model, not give the traders all the excess capital above model. The compensation structure is wrong in banks.

"That's not the fault of mathematicians; it's the fault of using models as accounting tools."

When it comes to the use of models for accounting or the use of models for marking to market, Avellaneda is of the view that these models have to be examined within stress scenarios and subjected to strict stress scenarios to create a band of extreme values that a portfolio could take, to find out how you will cover those risks with funding, with money. In the context of his current work on clearing houses, the whole idea of central clearing is to provide models that are going to withstand systemic risk, putting everything to a central counterparty, but one equipped with a system of liquidity and models that allows you to catch and essentially survive crashes, rather than having a network of transactions. He believes that modeling is coming back that way, and the fun part there is that the work is in places where models are well accepted – listed derivatives exchanges, for example – and in places where models are not like credit default swap clearing or swaption clearing, where models are accepted but the data is very difficult to get. Avellaneda has identified the need for an honest assessor between regulators and the regulated.

"I am having fun on central clearing and central counterparty, and I'm making money with running a business on this idea of central clearing, because it basically has to assess the business risk of a company that is using models to manage a portfolio of counterparties. So, the regulators will ask if this business is sound, if we will have to open our wallets and pay for the mistakes of the clearing house, and if this clearing house is sufficiently capitalized. And this is an interesting problem because if you demand too much margin, then no one will want to central clear, so there's no business; if you demand too little margin, then you are getting ready for the next crisis, and this kind of project involves the two sides: the central bankers and regulators, who do not want to be in an embarrassing position but want some stuff done; and the central clearing people, who want to have a lot of clients but don't necessarily want to have huge margins coming in."

"That creates a dichotomy where a quant can do some work. I cannot do work in a bank where I am always the messenger with bad news, always telling people you have to manage risk today; we take money from our deposits and we buy long-term assets and do trading. What are you telling us, like the guy from Deutsche Bank, Eric Benarzi? 'Oh, I

discovered you guys were short $12 million, yes, but that was three years ago – now we're not, go away! So, now I'm suing you!' You know risk management in a bank – you are going to be bullied by every junior trader. Go away! I was also a trader and I hated it when risk managers came with a question I couldn't answer; I was super-embarrassed because the idea was that somehow there was no tension – you know why? Because bank management always takes the side of the trader, because that's where the money is – it's like that poor guy from Barings. As long as he was making money in Singapore, nobody was asking any questions. When you make money, people won't ask questions. Therefore, senior management pay traders more, and listen more to traders, than risk management. This happened in J.P. Morgan recently, with the whale. The kind of risk management company that I want to build is really in the middle, between two people who are different; they have different objectives – of course, one will pay me but I will be independent. Without going into details, a risk management consultant will be paid a fee by someone who wants to be audited, but if I am a pushover, a bad accountant, a bad auditor, then my business is over. I have to make reports based on tests and stress tests. I believe there is a life for quants, provided they remain fiercely independent and compensate themselves well, but remain fiercely independent.

Reflecting on the view that Courant takes on his activities on Wall Street allows Avellaneda to take stock of his career. He recalls that Henry McKean, who was the School Director at the time he made his first forays into finance, would say: "I had a student who's running a department in Wall Street; such and such was a roommate of the Dean and he's now such and such at Salomon Brothers." Avellaneda discovered that what he was doing had been done all along. Wall Street has always gone to science and asked to have math explained to them.

"By the time I entered finance, I had already become a tenured senior member of the faculty, and the faculty at Courant are very, very good. We have three or two and a half Abel Prizes, so these guys, if you say you are interested in something, then they will say, 'Hmmm, well, that must be interesting because he's interested in it' – it doesn't mean that they should be, but they are completely open minded. Every time I run into someone in the elevator, they'll ask me: 'What do you think about the Volcker rule?' or something – it's more like we are very clubby in a good way.

Downloaded by [illegible] on [illegible]

Downloaded by [redacted] on 2015-03-27

MARCO AVELLANEDA

"Courant's idea was to take the best people, put them together, and something good will happen. Courant used to be like a school, the director's like a dean, so we don't have to explain to the university who we hired. In the old days, people who were considered to be good did the hires: period. There was some looking over, but, come on, let's face it –how many people understand mathematics in the world? Very few, right? So, if the Courant guys say this guy is good, then he's good – that was it. There was very little politics; Courant believed in some sort of anarchic good, where whatever he thought was good was good and that was it. That doesn't mean that people gave me a pass – I think it was a price to pay. In retrospect, in Courant I never had a problem; I mean, I did have a problem, in that I wasn't allowed to be in the committee, but that's not a problem because it turned out to be good. I had more time. I wasn't involved directly in the hiring of pure mathematicians, I was involved in consulting on things relating to applied math. They were very shy of hiring people who were 100 percent in math finance, thinking they would not know enough math, that they couldn't teach; they had to follow the Courant principles. The person had to be outstanding, and it's hard to judge that in mathematical finance.

"I'm kind of like their window, because they've known me since I was a child, practically, since I was 30. So, they will say, what do you think of such and such? Whatever I answer, they will interpret; they will ask what I think of this professor from Imperial… I'll say, well, he's a great guy! They know that I might say that because I like him – they can discount all my idiosyncrasies because they know me … but even with the purest mathematicians, I have a surprisingly cordial relationship. The funny thing for me with Wall Street is that I grew up in Courant, scientifically; when I went to Wall Street, to Morgan Stanley, I had no idea what I would find in terms of people. I discovered the world. I discovered there were smart people, there were very professional people, but it was not the kind of smarts that we have at Courant. These people are not the creators of science, they are the creators of business or great executives, they know how to manage people but there are all sorts of different talents – I have been fortunate to see many different types of talent and Courant was never a hindrance.

"I remember, once I ran a hedge fund in Paris, and I told the head of the math department that I was on a sabbatical. Risk or Bloomberg published a headline saying: 'Hedge fund wizard quits NYU,' so I get a call saying: 'You quit NYU? You didn't tell me? I'm your boss!' No, no, that's just the media, you know – they will say whatever they want, thanks! I will be there, I will teach, I will be there in September. You never know if a university will be good or bad as a fall-back place. I think that you carry a lot of weight, but, hey, that's who I am. I don't have that choice. I think that my background makes it okay to be university based.

"Before, when I went to an interview in Wall Street, the invariable question I got if they didn't like me was: 'Are you going to leave NYU?' But then, as the years went by and I did not leave NYU, that question started being left out. 'How do you see your job here, as a consultant? Maybe I'll take your sabbatical'… case done! It is very difficult to operate in an academic environment and be good in business. I know very few people that can do it, few can. I know my limitations but it is a wonderful environment to be in – not necessarily to have meaningful intellectual conversations, you know, but it's like, you have your team, you're with quality people, you will look into what you do and try to look for your excellence there. Whether in business or whatever, you want to make them feel proud of you; 'Oh there's this guy, he's doing great stuff' – they want to be able to say something good about you in a coffee conversation, like he has a hedge fund or he's the Quant of the Year; they want to be able to say something good. Not: 'Oh, poor guy, he's depressed' – that's the point.

"Once there was this guy, my colleague, Raghu Varadhan; he said something very nice to me. We were having dinner in Paris with our wives

and we were talking about the meaning of research and everything, and he said that tenure was invented because in those days, if you did very exotic research and you had no students, you ran the risk of being fired, so in the old British universities, the old European universities, in those days you were basically supported by your students. If you had no students, then you couldn't do research. So, the idea was to create a tenure function that essentially would protect you from being in such a weird research mode and losing all your students, and you still needed to get money to live. You were allowed eccentricity, if you like, and he said, look, just be as crazy as you can be, as exotic as you can be, don't conform to what you think a mathematician should be, be yourself. And that's what I tell my students. They'll say, oh, you're a mathematician, you have to prove theories, but actually maybe not; maybe you can be a mathematician who doesn't prove theories, you know what I mean? You make your own math. Oh, but then you have to write everything formally, no! Maybe you're a mathematician who just writes prose; to have that level of freedom, you have to be convinced that you want to do your best, that's all.

"I've been given complete freedom; I've been told: 'If you don't burn down the university, you're fine. You can do whatever you want – we don't really care.' The first time I taught derivatives, I put a course description in the Courant Bulletin and someone from the Business School told me I couldn't do that because they taught that subject. They said: 'You are basically encroaching on our head count,' and I said: 'Okay.' In fact, this gave me a pointer that this is something I should be doing because I've never heard of someone doing a math class and receiving a letter from another school telling them they can't do it; I thought that was beautiful. What I'm doing must be important because other people care. If I do some topology of four-dimensional manifolds, no one will say anything. But if I suddenly teach a class on derivatives, then all of a sudden I get a call that I can't do it! So, I said: 'No, this is derivatives with differential geometry for Ph.D.s.' Then the guy said: 'Oh, okay, you can teach that' … then I went ahead and taught what I wanted anyway – Marc Rubinstein, Duffie.

"This was a great opportunity because all of a sudden I saw that someone didn't want me to do it; you can get an intuition that you are going into something interesting because you are finding someone opposed to it. If I was going to teach something silly, like the mathematics of composite materials, which is not silly – I used to teach that a lot – then no one would care. You just had to make sure that no one else was teaching it in exactly the same way, and then not even that really. But when you can see that you are threatening someone, and I thought, well they don't know as much math as I do, so maybe I will be able to… So, I had a few years that I had problems from the business school – not problems, more like spats and people sending me evil messages or coming to my classes and sticking their nose in the air, sending graduate students.

"But that was part of the connection between mathematics and Stern. We are now connected, both Stern markets having Courant as the quant factory, and we say that Stern is the place we go to for expertise in theoretical finance. But the way we grew to that, we were not buddy-buddy and said: 'Hey, let's do it!' There was a lot of fighting. For example, I remember going once with Varadhan to the head of Stern, who said: 'That's all very good, but I don't know who you are, so get famous and then we'll talk!' But he was being very, very clear; he was saying, we're talking business, you guys aren't, so don't come here. You're an intruder; pay your dues and we'll do a joint program. In top schools, that's not unusual, because everybody wants to be the best in their field.

"Mathematicians tend to intrude on other people, because they are naïve. They are like: 'Oh, physics! Yes! Schrodinger's equation!' Now, you can't just do quantum mechanics because you know equations! You have to understand the physics. Same thing in finance: 'Oh! Black–Scholes! I can do something with that equation, so I can be in finance!' Then, you write a paper quickly and get published. That is annoying for people who spend years and years thinking and looking at data, developing intuition and a trade based on that. It's not so much annoying as … most of the time, you have already thought about it, and most of the time people are, like: 'okay, yeah, that's a good idea.' Then, they ask: 'Is it publishable or not?' You're like: 'I don't know, honestly – not in a journal that I would read but if you want to go ahead.' Then, they are like: 'Okay, I'll go ahead!' Pure mathematicians tend to go into fields and produce a certain amount of knowledge but they remain applied mathematicians. Look at Wilmott, Howison, and DeWinn. Sam Howison continued to do a lot of mathematics, not associated with finance; DeWinn, I don't know personally, but Wilmott went into finance and became Wilmott Finance – not Wilmott Continuum Mechanics. I'm kind of more that kind of character, but I let the field transform me intellectually and economically; I let myself go, as if I were in a river. But I'm not saying that I don't like the other stuff. If I could write papers on physics, I would, except that I don't have any time … or any ideas!"

"I've been given complete freedom; I've been told: 'If you don't burn down the university, you're fine. You can do whatever you want – we don't really care."

Downloaded by [redacted] on 2022-07-05 07:37:22