Dynamic Pricing for Online Marketplace Sales

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Introduction

Wang Fang Li had just graduated from a Masters in Management Science and Engineering at Columbia, and was eager to put the material she had learnt to good use. She had been particularly fascinated by her pricing classes, and was convinced there was value to be captured by applying these concepts to an online retail business she had been running since her teenage years.

Wang Fang's business leveraged her familiarity with various Chinese manufacturing companies (her parents had spent most of their lives in the business) and the increase in popularity of online retailing in the US and Europe. She noticed that a number of products were being sold on these online platforms at prices that were vastly higher than the wholesale prices she could procure them for in China. Wang Fang assumed that difficulties navigating the local manufacturing landscape and the lack of familiarity with the key players there prevented others from procuring these products themselves and undercutting the current sellers.

She had quickly jumped on the opportunity, and had created a thriving business procuring various items from electronics to household goods in China, and selling them on third party marketplace platforms such as Amazon and EBay at prices significantly lower than current offerings.

She knew, however, that the methodology she used to price these items left much to be desired. Her approach was simply to look at the price she paid per unit to procure each item, and to add a fixed margin to each of those items before selling them. This type of

pricing, called cost-plus pricing, is attractively simple, but often fails to capture a significant amount of value for the seller. Indeed, whilst the method guarantees a profit and captures a significant portion of the demand if the prices are low enough, it is often the case that profitability can be increased by increasing prices (and *losing* some of that demand, but making more from each sale), or by lowering prices (and making less from each sale, but *increasing* demand). She was worried that this phenomenon was particularly acute in her case because of the large gap between the wholesale prices at which the procured the items and the prevalent prices in the market.

Using the methods she had learnt in her Masters, Wang Fang was eager to re-vamp her pricing methodology and see if she could increase profitability. She had heard of a number of commercially available tools that offered to help online retailers with that task, but she first wanted to experiment herself to get a better feel for the problem before potentially moving to one of these tools.

The rise of online retailing

The growth of online retailing, and the increase in prominence of this channel in retail, is well-known and well-documented. Indeed, e-commerce sales have grown from 4.2% of total retail sales in the US in 2010 to 9.1% in 2017. From a revenue perspective, growth in e-commerce sales has been even more impressive – $34 billion in sales in the first quarter of 2009 have grown to $115 billion in the third quarter of 2017.[i] If anything, these numbers underestimate the impact of the channel on the retail landscape over the last decade – they only reflect items that were actually purchased through online channels, and ignore other less direct impacts of the proliferation in online retail. A few examples of these less direct impacts include

- The relative ease with which price-sensitive consumers can now compare prices across channels and retailers. Price comparison engines such as those provided by Google come to mind, as well as the simple ability to switch websites.

- Retailers' increased ability to easily and frequently change prices in an online setting. This practice is so prevalent that entire websites have made it their mission to keep track of these price changes over time – camelcamelcamel.com, for example, keeps track of prices changes in Amazon products.
- Various changes brick-and-mortar stores have had to make to their day-to-day operations to boost their value proposition compared to online shopping. Best Buy's recent turnaround has been widely praised as an example of a brick-and-mortar store providing new in-person services to compete against online retailers. (The secret, according to Hubert Joly, Best Buy's chief executive? Focus on humans.[ii])
- The emergence of "omnichannel" initiatives, in which brick-and-mortar stores leverage their considerable physical footprint to fulfil online orders, or to add value to their online channels (Uniqlo, for example, now operates a "buy online, pick up in stores" program, using their stores as distribution centers). Alternatively, some consultants are now advising brick-and-mortar stores to use their stores as "showrooms" for their products, shipping them directly to their homes.[iii]

The first two points above have led to an increased importance in pricing and the ability to price items scientifically and systematically, and will therefore of particular relevance to us in this case. We will return to these trends in the next section.

The fast-growing world of e-commerce can broadly be broken down into three categories

- **Business to Consumer** (B2C) e-commerce is the most traditional form of online shopping – business sell items to consumer through their own websites; the websites take the place of traditional shopfronts. Amazon is by far the most popular e-commerce website by visitor as of March 2017 – it boasted 183 million unique visitors per month. The second most popular website, Wal-Mart, comes in far behind at 87 million unique visitors per month (nevertheless quite a feat given its impressive concurrent brick-and-mortar presence not shared by Amazon).[iv]

- **Business to Business** (B2B) e-commerce consists of situations in which companies such as wholesalers or manufacturers exchange goods or services. Companies in this category include traditional B2B business expanding into the online arena, as well as business that provide high-tech services to other companies (for example, Slack, Cloudera, AppNexus, etc…) The transition of non-tech B2B business to digital channels has been slower than that of the B2C business, but is becoming increasingly important. Inspired by the convenience of their personal shopping experiences, buyers at business are increasingly expecting the same convenience for their business purchases. Indeed, a 2014 Forrester survey found that 49% of buyers surveyed prefer to make work-related purchases on the same websites they use for personal purchases.[v]
- **Consumer to Consumer** (C2C) e-commerce involves transactions between consumers. More generally, C2C e-commerce can be defined as any online sale in which the platform on which the sale occurs is not owned and operated by the seller of the product (this definition is somewhat more useful in a world in which it is so easy for consumers to operate as business themselves – Wang Fang Li, for example.) There is a proliferation of platforms, both online and app-based, that offer such platforms to consumers seeking to sell their wares. Amazon and eBay are the most popular such platforms, and their growth has been vertiginous. The net revenue from third party sales at Amazon have gone from $11.75B in 2014 to $22.99B in 2017[vi], and a staggering 50% of items sold on Amazon are sold by third party sellers[vii].

Thus far, Wang Fang Li's business had been operating squarely in the C2C business – she had neither the desire nor the inclination to operate her own e-commerce platform, and was happy to continue using Amazon's platform. And indeed, her business model was far from original – many business have sprung from the idea of being a "middle layer" between cheap manufacturers in China and consumers in the US[viii] – so much so that some C2C e-commerce platforms are even suggesting their clients might want to manufacture or procure their products there[ix]. She had managed to remain competitive in spite of this

competition, but it made her particularly eager to address the pricing problem as a further way to keep an edge over the competition.

Pricing and dynamic pricing in e-commerce

We take it as a given – at least in a traditional retail setting – that each item has a well-defined price and that (with very few exception) every customer will be quoted the same price for the same item. This was not always so. Indeed, when John Wanamaker opened his store in 1861 with a Quaker-inspired principle that "if everyone was equal before God, then everyone would be equal before price," the concept was revolutionary. He put an end to haggling and preferential treatment for certain customers, by offering one price for everyone. Another famous proponent of this approach, also Quacker, was the New York merchant Rowland H. Macy.

In one sense, this innovation was detrimental to the merchants. By eliminating the practice of haggling, it curtailed their ability to charge difference prices to customers based on their perception of how willing the customer would be to pay. However, it also came with substantial benefits. Training every staff member to haggle was an expensive endeavor, and fixed prices eliminated the need to do this. Furthermore, fixed prices allowed for more streamlined operations in stores, gave a greater measure of income predictability, and, crucially, opened the road to printed retail adds stating the price for a given good. Many merchants saw the benefit of such an approach, and for the last 150 years or so, this principle has been taken as a given in a wide variety of retail settings.

In the absence of haggling, many merchants attempted to recover some of the lost profits through customer segmentation – offering differentiated products to appeal to different customer segments, at different prices. In the 1920s, for example, General Motors bucketed its various car brands into well-defined price brackets. Supermarket chains made extensive use of couponing, allowing price sensitive customers who may otherwise have been deterred by high fixed prices to buy the products anyway.

Aside from these specific techniques, however, retailers by and large had to set uniform prices for their products, and the most common method by far was cost-plus pricing, in which retailers took the cost of procuring the good and added a fixed margin to it to determine the good's fixed price.[x] The downsides of this approach are many, but for the sake of the discussion at hand, the most egregious is the fact that it does not take into account the market's ability to pay for the item. Indeed even if the item is very cheap to procure, it may be advantageous to give it a hefty price tag if there is tremendous appetite for the item in the market, and vice-versa. Why, then, is this pricing method so common? Part its appeal is its simplicity – it doesn't rely on any complex mathematics, and can easily be understood. Another important part of its appeal, however, is its ease-of-use; in a pre-digital retail setting, it was very difficult to collect enough information about the market to set prices based on real-life data. Prices could not be changed fast enough to gather enough useful information about the demand curve.

The advent of online retailing discussed in the previous section, however, radically changed the dynamics of these interactions in two subtly different ways. First, in an online setting, retailers were able to change prices much more regularly, thus increasing their ability to obtain a good estimate of the demand curve. Second, retailers in an online setting are able to offer different prices to different customers, exploiting differences in price sensitivity among different consumers.

Anyone who has used Amazon.com will know that the practice of regularly changing prices is now widespread across the internet. Indeed, in some cases Amazon has been found to cut the prices of products advertised by third-party sellers on its own platform, and suffering a loss in profits on these products as a result.[xi] There is also widespread evidence that some retailers are engaging in so-called "first-degree price discrimination", whereby customers with a higher willingness-to-pay are presented higher prices for a given product.[xii] At one time, for example, the travel platform Orbitz, presented more expensive prices to Mac users than PC users.[xiii] However, such measures can be very unpopular, and some retailers are shying away from fully adopting them. Indeed, Amazon has repeatedly claimed that it does not change prices to "experiment"

on its users or to alter profitability, and Netflix does not engage in first-degree price discrimination, despite evidence that it could considerably improve its profit.[xiv]

Nevertheless, even without first-degree price discrimination, there is much that can be done to optimize the single price offered to all customers by matching it to their willingness to pay. Given the limited amount of information on each customer that Wang Fang had access to on the platforms she used to sell her products, she initially decided to go down this route.

Preliminary analysis

Wang Fang's plan was eventually to have a dynamic pricing engine – one that could adjust prices automatically day-by-day based on observations on previous days. In itself, this idea is not difficult to implement – she already had a system in place that systematically changed prices day by day and observed resulting demand. However, it could take many days of experimentation to get a reliable estimate of the demand curve – these days were costly, because they involved offering the product at a less-than-optimal price. Furthermore, even once this data had been collected, Wang Fang Li was worried she was not using it correctly to determine the final optimal price.

Despite its shortcomings, Wang Fang's current method provided her with valuable data. She was hoping to use this data to obtain the true demand curve for one of the products she sold, and to then use that to test any subsequent methods she came up with.

She decided to use one of her most popular products to test this approach – a 1 GB basic USB stick, particularly popular in the US market. Exhibit 1 summarizes the data available on this particular product. Note that due to a very large bulk-order of the product Wang Fang placed before the start of this study, she decided to maximize revenues rather than profits – you can therefore assume the marginal price for a USB stick is 0.

pricing_data.csv
Describes the price of the USB stick over the period in question. Comprises the following columns:

- **product_id;** unique identifier for the product
- **start_date;** the date and time on which the price in question came in effect
- **end_date;** the last date and time on which the price in question was in effect
- **price;** the price of the product specified during the period specified

sales_data.csv
Describes sales data for the USB stick over the period in question. Comprises the following columns

- **product_id;** unique identifier for the product
- **order_id;** a unique identifier for this order
- **date_time;** the date and time of the sale
- **quantity;** the number of items bought

Exhibit 1: description of datasets for preliminary analysis

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[i] US Census Bureau and US Department of Commerce Surveys, November 2017

[ii] "Best Buy's Secrets for Thriving in the Amazon Age", Kevin Roose, The New York Times, September 19th, 2017

[iii] Strategy& 2017 Retail Trends report, by Nick Hodson, Christopher Perrigo, and Douglas Hardman

[iv] "State of the U.S. Online Retail Economy in Q3 2017"

[v] "Building the B2B Omni-Channel Commerce Platform of the Future", Forrester Consulting thought leadership paper, November 2014

[vi] Amazon.com Annual Report 2016

[vii] Amazon Investor Relations press release, Q3 2017 (link)

[viii] See, for example, "Made in China – and Straight to your Amazon box", USA Today, January 26th, 2017

[ix] "How to Find a Manufacturer or Supplier for Your Product Idea", Richard Lazazzera, Shopify Blogs

[x] A 1984 study of German industry quoted in Godin and Conley (1987, p. 58), for example, found that about 70% of companies used cost-based pricing in some form

[xi] https://www.cnbc.com/2017/11/05/amazon-discounts-third-party-sellers-products-as-retail-competition-stiffens.html

[xii] "*Detecting price and search discrimination on the Internet*", J. Mikians, L. Gyarmati, V. Erramilli, and N. Laoutaris, Proceedings of the 11th ACM Workshop on Hot Topics in Networks

[xiii] https://www.wsj.com/articles/SB10001424052702304458604577488822667325882

[xiv] "*First-Degree Price Discrimination Using Big Data*", Benjamin Reed Shiller, working paper