

WHARTON FINANCIAL ANALYTICS

Data  
Lab

# Diamonds

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Michael R. Roberts is the William H. Lawrence Professor of Finance at The Wharton School of the University of Pennsylvania. He developed this data lab solely for the purpose of class discussion. The lab is not intended to serve as an endorsement, source of data, or illustration of effective or ineffective decision making. Although based on real events and despite occasional references to actual companies, this lab is fictitious and any resemblance to actual persons or entities is coincidental.

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In the summer of 2020, Kerry Bates was preparing to open Schutte, a retail jewelry store in West Los Angeles. Her business model was specializing in custom diamond jewelry, providing clients with a more flexible and affordable alternative to name brands, such as [Tiffany & Co.](#) and [Cartier](#). A critical component of her business was her profit margin. Kerry wanted to ensure she obtained loose diamonds at the lowest cost while maximizing the price she could charge for her finished jewelry. Thus, she faced two challenges: identifying high-quality but relatively inexpensive diamonds and marking-up her retail prices without going beyond industry norms.

## Diamond Industry<sup>1</sup>

The diamond industry can be described in terms of four vertical segments.

- **Miners and producers** mine, sort, and sell, “rough diamonds,” that is, diamonds that are uncut and unpolished.
- **Cutters and polishers** buy from producers rough diamonds they cut and polish.
- **Jewelry manufacturers** create finished pieces.
- **Retailers** sell the finished pieces to consumers.

Most companies fit uniquely into one segment, though some are vertically integrated across two or more segments.

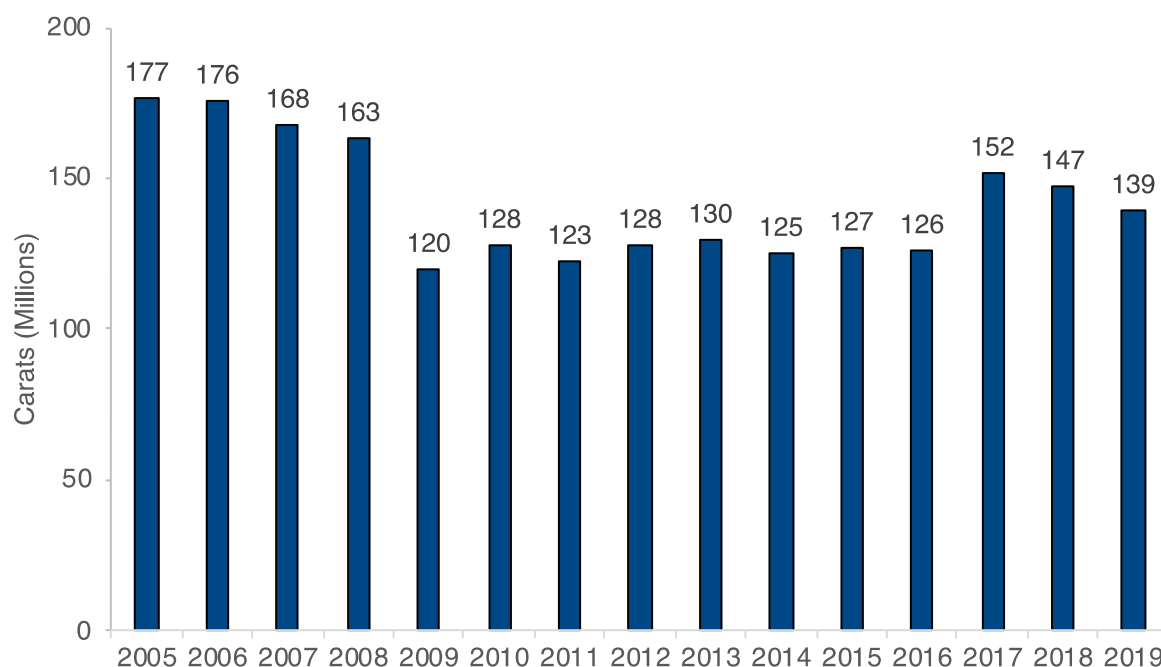
The first step in the supply chain begins with mining operations, which produced 139 million carats of diamonds in 2019 (see Figure 1).<sup>2</sup> Table 1 shows that the large majority of this output is controlled by five producers: Alrosa, De Beers, Debswana, Rio Tinto, and Dominion Diamond. Debsawana is a 50:50 joint venture between De Beers and the Botswana government. Coupled with the relatively small production of Dominion, this joint venture suggests that global diamond production is controlled by three firms.

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<sup>1</sup> Source references for this material include “[The billion dollar business of diamonds, from mining to retail](#),” by Bob Pisani, August 27, 2012.

<sup>2</sup> A carat is 0.2 grams

**Figure 1. Global Annual Diamond Production**



Source: [Statista](#).

**Table 1. Top Diamond Producers of 2019**

| Producer           | Country  | 2019 Output (million carats) | % of Total 2019 Output | Mining Locations                        |
|--------------------|----------|------------------------------|------------------------|---|
| Aloosa             | Russia   | 38.5                         | 27.7%                  | Russia, Angola                          |
| De Beers           | England  | 30.8                         | 22.1%                  | South Africa, Botswana, Namibia, Canada |
| Debswana Diamond   | Botswana | 23.3                         | 16.8%                  | Botswana                                |
| Rio Tinto Diamonds | England  | 17.0                         | 12.3%                  | Western Australia, Canada, Zimbabwe     |
| Dominion Diamond   | Canada   | 6.7                          | 4.8%                   | Canada                                  |

Source: [Profiling the top five largest diamond mining companies in the world](#), NS Energy, January 7, 2021

Each of the big three producers – Aloosa, De Beers, and Rio Tinto – are vertically integrated across the industry segments. In addition to mining, Aloosa sorts and sells rough diamonds through several subsidiaries including the Yakutsk Diamond Trading Enterprise of Aloosa (YAPTA), Brilliantly Aloosa, and the United Selling Organization (USO). Brilliantly Aloosa also cuts and polishes stones for sale to large jewelry retailers.

De Beers is perhaps most well-known among the big three, having long been criticized of monopolistic behavior and selling “conflict diamonds.”<sup>3</sup> Based on its recent market share and declining revenue growth, its monopoly control over the diamond market is no more. In addition to mining, De Beers sells and distributes rough diamonds through its Diamond Trading Company (DTC). De Beers also maintains a retail arm via a joint venture with Louis Vuitton Moët Hennessy through its De Beers Diamond Jewellers Ltd.

Rio Tinto Diamonds is part of the Anglo-Australian mineral mining multinational Rio Tinto Group. The London-based company markets and sorts its rough diamonds in Antwerp, Belgium.

Contributing to the cost of diamonds is the difficulty of extraction. The Jwaneng mine in Botswana is the “richest” mine in the world with an estimated 166.6 Million carats as of December 2018.<sup>4</sup> Yet, to get 1.4 carats (0.0006 pounds) requires the removal of 2,000 pounds of rock. The mine excavates approximately 8 million tons of rock to generate \$1.5 billion in revenue at a 24% profit margin.

Historically, most of the cutting and polishing was done in the major diamond centers of Antwerp, Belgium; Tel Aviv, Israel; and Russia. Much of this work has moved to India and China since 2010 because of lower labor costs, though larger stones, in excess of 3 carats, continue to be cut and polished in the major diamond centers.

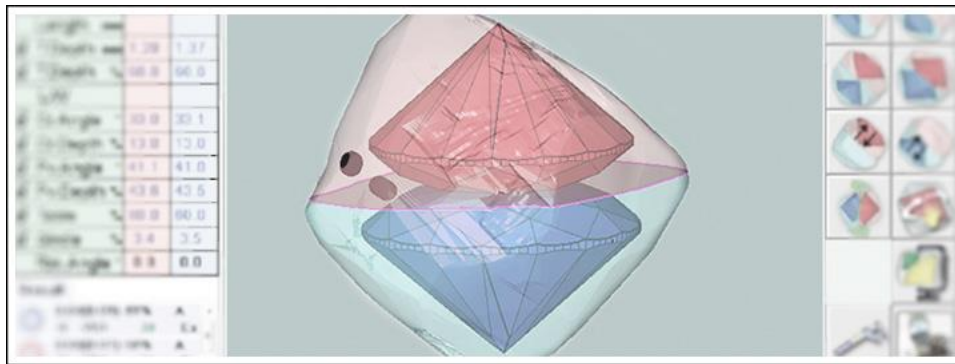
Cutting is an expensive process as most diamonds lose between 50 and 60 percent of their weight before polishing. The process begins by marking a rough diamond using a 3D laser scanner. The goal is to maximize the potential of the rough diamond, which may mean creating multiple cut diamonds from one rough diamond. Figure 2 shows a screenshot of a rough diamond mapping, in which two cut stones will be created from one rough diamond.

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<sup>3</sup> For a detailed account of De Beers history see “The Last Empire: De Beers, Diamonds, and the World” by Stefan Kanfer.

<sup>4</sup> See “[The world’s top 10 biggest diamond mines](#),” February 14, 2020.

**Figure 2. Diamond Mapping**



Source: [Cape Town Diamond Museum](#).

After mapping, the diamond is marked and cut by either a cleaving or sawing process. In the former, the diamond is broken into pieces by hammering a chisel along the grain of the diamond, effectively breaking it between the planes of the crystal. Sawing is more difficult and originally required circular saws with diamond dust. More recently, lasers are proving a more precise and efficient method for cutting diamonds. Once cut, diamonds are shaped in a process known as bruting or girdling, often using another diamond, before they undergo faceting and polishing.

Cut and polished diamonds are then sent to jewelry manufacturers, of which there are more than 10,000 globally. Some of the largest global jewelry manufacturers include Chow Tai Fook, Louis Vitton Moët Hennessy, Rajesh Exporters, Chanel, Cartier, Signet, Tiffany & Co, and Bulgari. Most manufacturers do not brand their work, and 80% are in India and China. However, branding is estimated to play a large role in jewelry markups.

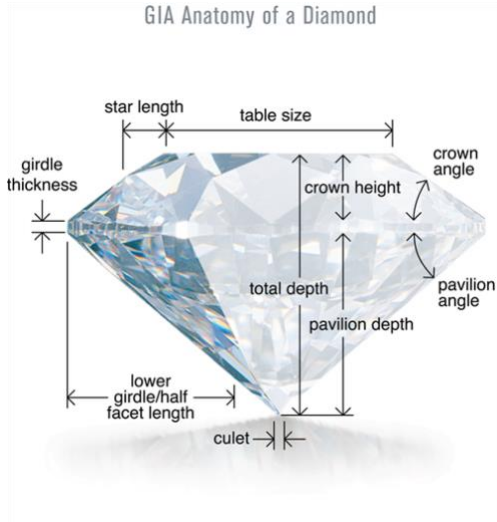
Retailers are smaller and more fragmented than most manufacturers, though there is overlap between the two groups (e.g., Cartier and Tiffany & Co.). While there were upwards of 250,000 in 2012, the number of retailers has been declining as larger name brand and online stores become a bigger part of jewelry sales.

## Diamond Features and the Four C's

Figure 3 illustrates the anatomy of a round, brilliant cut diamond.

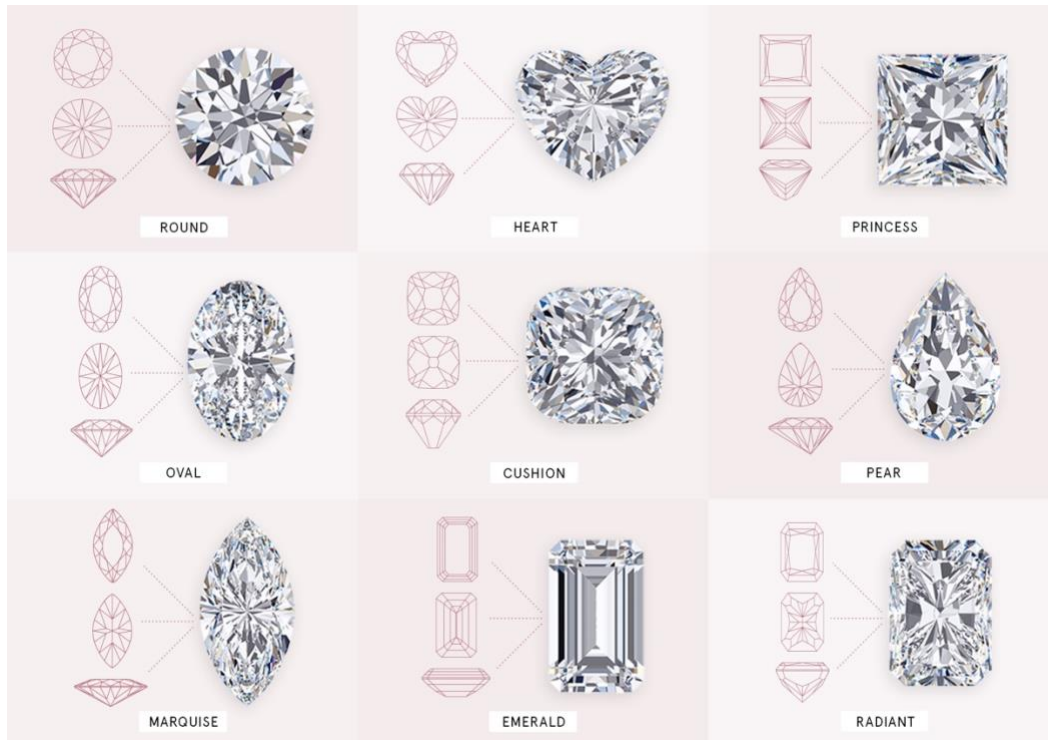
Figure 4 presents several other, common shapes in which diamonds come.

**Figure 3. Anatomy of a Diamond**



Source: [Diamond Anatomy. Explained](#), GIA.

**Figure 4. Diamond Shapes**



Source: [Kay Jewelers](#).

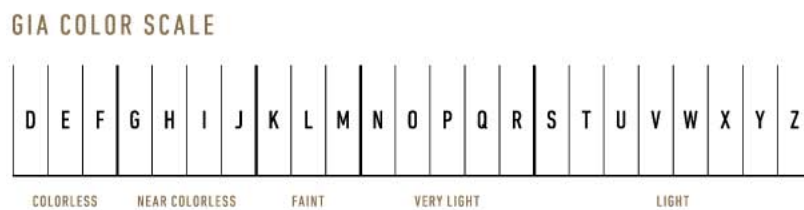
While diamonds come in a variety of shapes, the distinguishing features that determine a diamond's price are referred to as the "4 C's": Carat, Color, Clarity, and Cut. All C's other than carat are determined by trained diamond graders.

Carat is a measure of weight and size. One carat equals 200 milligrams. For diamonds under 1 carat, their weight is often expressed in hundredths or "points." For example, a 0.25 carat diamond may be referred to as a "25 pointer." For diamonds larger than one carat, the weight is expressed in carats, e.g., 2.16 carats. All else equal, larger diamonds tend to be more expensive.

**The color of a diamond is graded on a letter scale varying from "D" to "Z." Figure 5 depicts the color scale and provides color descriptions for different groups of grades.**

Figure 6 presents four different color diamonds. From a price perspective, less color is more valuable. Therefore, diamonds graded "D" through "F" – colorless – are the most valuable, grades "S" through "Z" the least valuable, all else equal.

**Figure 5. Diamond Color Scale**



Source: [Gemological Institute of America, Inc.](#)

**Figure 6. Diamond Color Examples**



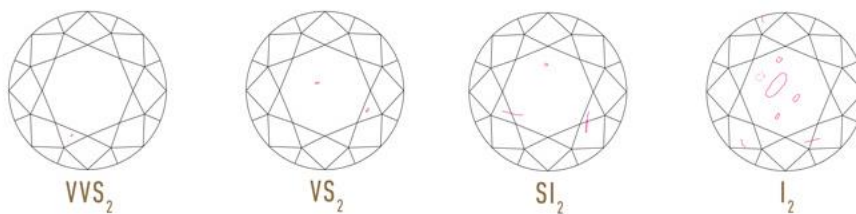
Source: [Gemological Institute of America, Inc.](#)



Some diamonds are outside the normal range of color (D through Z) and are referred to as fancy-color diamonds. There are no guidelines for the use of the term “fancy-color.” However, the industry is largely in agreement about what diamond color range is customary for ordinary diamonds. Fancy-color diamonds are either yellow or brown with more color than a “Z” graded stone, or they exhibit a color other than yellow or brown (e.g., rose).

Clarity refers to the absence of inclusions and blemishes. Inclusions form when small crystals become trapped in a diamond as it is forming. These crystals can result in visible irregularities in the atomic structure as the diamond grows. Figure 7 illustrates different degrees of inclusions, along with the corresponding clarity grade. Figure 8 presents the entire clarity scale, and Table 2 presents a verbal description of the different ratings. The size, position, and visibility of inclusions can have a significant impact on diamond clarity and, ultimately, value.

**Figure 7. Diamond Clarity Illustrations**



Source: [Gemological Institute of America, Inc.](http://www.gia.edu)

**Figure 8. Diamond Clarity Scale**



Source: [Petra Gems.](http://www.petragems.com)

**Table 2. Clarity Scale Descriptions**

| Clarity class                | Grade(s)      | Description  |
|------------------------------|---------------|--|
| Flawless                     | FL            | No inclusions and no blemishes visible under 10x magnification                                 |
| Internally Flawless          | IF            | No inclusions visible under 10x magnification  |
| Very, Very Slightly Included | VVS1 or VVS2  | Inclusions so slight they are difficult for a skilled grader to see under 10x magnification    |
| Very Slightly Included       | VS1 or VS2    | Inclusions are observed with effort under 10x magnification, but can be characterized as minor |
| Slightly Included            | SI1 or SI2    | Inclusions are noticeable under 10x magnification  |
| Included                     | I1, I2, or I3 | Inclusions are obvious under 10x magnification which may affect transparency and brilliance    |

Source: [Gemological Institute of America, Inc.](#)

Finally, cut refers to how well a diamond's facets interact with light. (Cut is often mistaken for the shape of a diamond.) It is the artistry and workmanship of the cutters and polishers that can generate a diamond whose proportions and symmetry deliver the intense sparkle often associated with a diamond as it refracts light. Table 3 lists and describes the different cut grades.

**Table 3. Cut Grades and Descriptions**

| <b>Cut Grade</b> | <b>Description</b>   |
|------------------|--|
| Excellent        | Excellent Cut Diamonds provide the highest level of fire and brilliance. Because almost all of the incoming light is reflected through the table, the diamond radiates with magnificent sparkle.                                     |
| Very Good        | Very Good Cut Diamonds offer exceptional brilliance and fire. A large majority of the entering light reflects through the diamond's table. To the naked eye, Very Good diamonds provide similar sparkle to those of Excellent grade. |
| Good             | Good Cut Diamonds showcase brilliance and sparkle, with much of the light reflecting through the table to the viewer's eye. These diamonds provide beauty at a lower price point.  |
| Fair             | Fair Cut Diamonds offer little brilliance, as light easily exits through the bottom and sides of the diamond. Diamonds of a Fair Cut may be a satisfactory choice for smaller carats and those acting as side stones.                |
| Poor             | Poor Cut Diamonds yield nearly no sparkle, brilliance or fire. Entering light escapes from the sides and bottom of the diamond.  |

Source: [The Diamond Pro.](#)

Together, the four C's – carat, color, clarity, and cut – are largely responsible for the value of diamonds.

## GIA “Certification”

GIA stands for the Gemological Institute of America, Inc. According to its website, the GIA is “the largest, most respected nonprofit source of gemological knowledge in the world.” Founded in 1931 by Robert M. Shipley and headquartered in Carlsbad, California, the GIA is a nonprofit institute dedicated to research and education in the field of gemology. In 1953, the institute developed its international diamond grading system and the “four C's” as the standard to compare and evaluate the quality of diamonds.

One often hears that a diamond has been GIA certified, but this is a misnomer. The GIA does not certify diamonds; rather, it grades diamonds based on their cut, clarity, color, and weight (carat). A sample GIA diamond report is provided in the appendix. GIA-graded diamonds provide some degree

of assurance to consumers that the quality of diamond is what they expect. However, GIA grading is not without controversy.<sup>5</sup>

### Schutte's Dual Mandate


Kerry decided to approach her twin challenge of identifying low-cost diamonds and a retail pricing strategy by first gathering data on loose diamonds from wholesalers. With this data, Kerry could create a model of diamond prices to (i) identify undervalued stones and (ii) impute the cost of stones for her competitors. Next, she collected data on retail prices of diamond engagement rings from some of her competitors. Combined with her predictive model of diamond prices and her knowledge of the materials and labor costs needed to set the stones, Kerry felt she could reverse engineer the price markups of her competitors.

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<sup>5</sup> See the [Wikipedia page](#) for a discussion of two separate bribery allegations and internal investigations in 2005.

# Appendix

Figure 9. GIA Diamond Report



# GIA®

This is a digital representation of the original GIA Report. This representation might not be accepted in lieu of the original GIA Report in certain circumstances. The original GIA Report includes certain security features which are not reproducible on this facsimile.

**FACSIMILE**

GIA REPORT  
**1388374145**

Verify this report at [GIA.edu](http://GIA.edu)

**GIA NATURAL DIAMOND DOSSIER®**

April 21, 2021  
 GIA Report Number ..... 1388374145  
 Shape and Cutting Style ..... Emerald Cut  
 Measurements ..... 4.35 x 3.25 x 2.20 mm

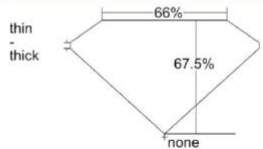
**GRADING RESULTS**

Carat Weight ..... 0.30 carat  
 Color Grade ..... J  
 Clarity Grade ..... SI1


**ADDITIONAL GRADING INFORMATION**

Polish ..... Excellent  
 Symmetry ..... Very Good  
 Fluorescence ..... None  
 Clarity Characteristics..... Twinning Wisp  
 Inscription(s): GIA 1388374145

**PROPORTIONS**



Profile not to actual proportions



The results documented in this report refer only to the diamond described, and were obtained using the techniques and equipment available to GIA at the time of examination. This report is not a guarantee or valuation. For additional information and important limitations and disclaimers, please see [GIA.edu/terms](http://GIA.edu/terms) or call +1 800 421 7250 or +1 760 603 4500. ©2017 Gemological Institute of America, Inc.

**GRADING SCALES**

|  |   |
|--|---|
| <p><b>GIA COLOR SCALE</b></p> <p>COOLEST</p> <p>D</p> <p>E</p> <p>F</p> <p>G</p> <p>H</p> <p>I</p> <p>J</p> <p>K</p> <p>L</p> <p>M</p> <p>N</p> <p>O</p> <p>P</p> <p>Q</p> <p>R</p> <p>S</p> <p>T</p> <p>U</p> <p>V</p> <p>W</p> <p>X</p> <p>Y</p> <p>Z</p> <p>HOTTEST</p> | <p><b>GIA CLARITY SCALE</b></p> <p>FLAWLESS</p> <p>INTERNALLY FLAWLESS</p> <p>VVS<sub>1</sub></p> <p>VVS<sub>2</sub></p> <p>VS<sub>1</sub></p> <p>VS<sub>2</sub></p> <p>SI<sub>1</sub></p> <p>SI<sub>2</sub></p> <p>I<sub>1</sub></p> <p>I<sub>2</sub></p> <p>I<sub>3</sub></p> |
|--|---|

Printed: 8/4/2021

Call to purchase: 888-565-7641

<https://www.bluenile.com/diamond-details/LD15882762>

Source: [Blue Nile](http://Blue Nile).

The two data files are

- 20-diamonds.pq, and
- 20-diamonds-competitors.xlsx

**Figure 10. Data Dictionary**

| File                       | Field      | Type     | Description  |
|----------------------------|------------|----------|--|
| <b>diamond</b>             |            |          | Loose cut and polished diamond prices and characteristics. |
|                            | dshape     | cat      | Diamond shape (e.g., round, cushion)                       |
|                            | cut        | cat      | Quality of the diamond cut                                 |
|                            | color      | cat      | GIA grading of diamond color                               |
|                            | clarity    | cat      | GIA grading of diamond clarity                             |
|                            | deliv_date | datetime | Delivery date of diamond if purchased                      |
|                            | price      | float    | Price of the ring in US dollars                            |
|                            | carat      | float    | Diamond weight measured in carats                          |
| <b>diamond-competitors</b> |            |          | Competitor solitaire engagement ring prices.               |
|                            | retailer   | str      | Retailer identifier  |
|                            | dshape     | cat      | Diamond shape (e.g., round, cushion)                       |
|                            | carat      | float    | Diamond weight measured in carats                          |
|                            | cut        | cat      | Quality of the diamond cut                                 |
|                            | color      | cat      | GIA grading of diamond color                               |
|                            | clarity    | cat      | GIA grading of diamond clarity                             |
|                            | setting    | str      | Band and setting material                                  |
|                            | set_size   | float    | Band thickness in millimeters                              |
|                            | price      | float    | Price of the ring in US dollars                            |



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